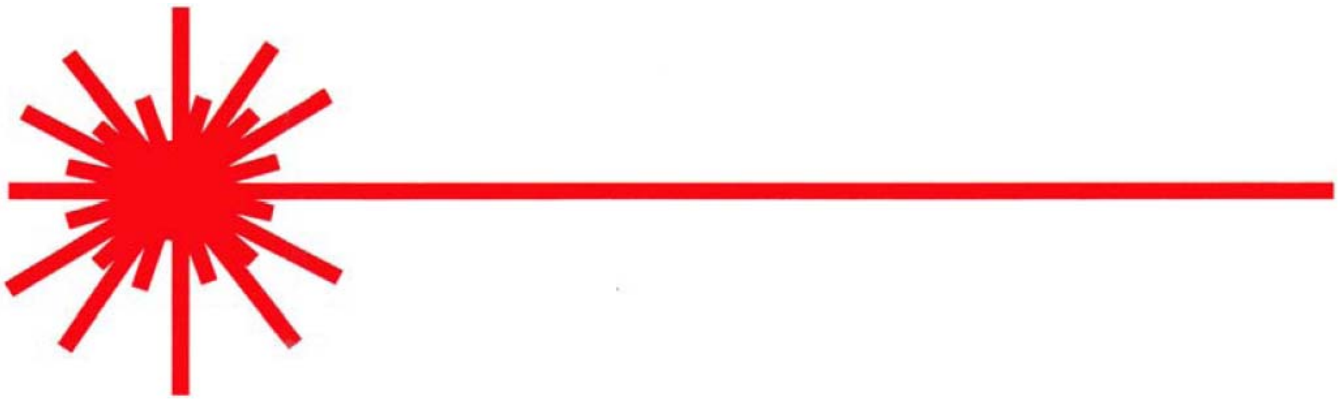
UCLA

Laser Safety Manual



Laser Safety Program

UCLA ENVIRONMENT, HEALTH & SAFETY

Laser Safety
Laser Lab Worker Training Log

501 Westwood Plaza, 4th Floor • Los Angeles, CA 90095
Phone: 310-825-5689 • Fax: 310-825-7076 • www.ehs.ucla.edu

USE THIS FORM TO DOCUMENT LAB-SPECIFIC LASER EQUIPMENT AND LABORATORY SAFETY TRAINING

Lab Location______________________________ **Principal Investigator** ____________________________

WORKER NAME	WORKER UID	TRAINING *	TRAINING DATE	INSTRUCTOR NAME	INSTRUCTOR SIGNATURE	PI SIGNATURE **

WORKERS ARE NOT AUTHORIZED TO USE LABORATORY LASER EQUIPMENT;
**** Without completing;***

- ***Specific Laser Equipment and Laboratory Safety Training***
- ***Initial UCLA EHS Laser Safety Training***. *Attach EHS Laser Training Certificate or copy to the Laser Lab Worker Training Log*
- ***UCLA EHS Refresher Laser Training every two years***. *Attach EHS Refresher Laser Training Certificate to the Laser Lab Worker Training Log*

***** Unless Laser Equipment and Laboratory Safety Training record is approved by Principle Investigator signature***

Laser Safety Officer x 47434

LASER LITE; A Quick Overview of Laser Safety

THE PRIMARY PURPOSE OF THE UCLA LASER SAFETY PROGRAM AND THIS LASER SAFETY MANUAL IS TO;

AVOID GETTING A LASER BEAM IN YOUR EYE

NEVER STARE DIRECTLY AT A LASER BEAM, EVEN WITH PROTECTIVE EYEWEAR

LASER LIGHT

- *Maintains strength over long distances*
- *Produces significant eye hazards at relatively low levels*
- *Concentrates to a very high intensity when focused by a lens*
- *Occurs in the Visible and Non-visible spectrum*

BIOLOGICAL HAZARDS

- *Can be laser beam and non-beam related*
- *Can occur at all wavelengths*
- *Occur mainly in the eyes and skin*

MOST INJURIES

- *Affect the eyes*
- *Occur during alignment*
- *Result from operator error*

PROTECTION

- *Eyewear must be worn for Class 3 and Class 4 laser use*
- *Eyewear must meet ANSI standards and be marked with Optical Density and Wavelength*
- *Appropriate skin protection is required for Class 4 lasers*

LASER CLASSIFICATION TABLE

Class 1 / 1M	**Maximum power output is a few microwatts. Visible spectrum output** Considered incapable of producing hazardous eye/skin exposure unless viewed with collecting optics (1M). Does not apply to open Class 1 enclosures containing higher-class lasers
Class 2 / 2M	**Maximum power output is < 1 mW. Visible spectrum output** Considered incapable of producing hazardous eye/skin exposure within the time period of human eye aversion response (0.25 s).unless viewed with collecting optics (2M)
Class 3R	**Maximum power output is 1 mW - < 5 mW. Visible and non-visible spectrum** **P**otentially hazardous under some direct and specular reflection viewing condition if the eye is appropriately focused and stable or if viewed with collecting optics.
Class 3B	**Maximum power output is 5 mW - < 500 mW Visible and non-visible spectrum** Present a potential eye hazard for intrabeam (direct) or specular (mirror-like) conditions. Present a significant skin hazard by long-term diffuse (scatter) exposure if higher powered and operating in 200 – 280 nm UVC ranges
Class 4	**Maximum power output is > 500 mW. Visible and non-visible spectrum** **Present** potential acute hazards to the eye and skin for all intrabeam and diffused conditions Potential hazard for fire (ignition), explosion and emissions from target or process materials.

EYE DAMAGE - WAVELENGTHS

WAVELENGTH	AREA OF DAMAGE	PATHOLOGICAL EFFECT
180 - 315 nm (Ultraviolet UV-B, UVC)	**CORNEA**; Deep-ultraviolet light causes accumulating damage, even at very low power	**Photokeratitis;** Inflammation of the cornea, similar to sunburn
315 - 400 nm (Ultraviolet UV-A)	**CORNEA and LENS**	**Photochemical cataract;** Clouding of the lens
400 - 780 nm (Visible)	**RETINA;** Visible light is focused on the retina	**Photochemical damage; Damage** to retina and retinal burns
780 - 1400 nm (Near Infrared)	**RETINA;** Near IR light is not absorbed by iris and is focused on the retina	**Thermal damage to cataract a**nd retinal burns
1400 - 3000 nm (Infrared)	**CORNEA and LENS; I**R light is absorbed by transparent parts of eye before reaching the retina	**Aqueous flare;** Protein in aqueous humor, cataract, corneal burn
3000 – 10000 nm (Far Infrared)	**CORNEA**	**Corneal burn**

LASER LITE; A Quick Overview of Laser Safety

LASER OPERATION GUIDELINES

OPERATORS MUST;

- Read the **Laser Safety Manual**
- Review **Standard Operating Procedures**, operating and safety instructions and laboratory-specific laser instructions
- **Be trained in laser safety** and specific laser procedures
- **Observe all written procedures, safety rules** and **properly use appropriate PPE**
- Be **authorized by the Principal Investigator**
- Be **directly supervised** by a person knowledgeable in laser safety
- **Wear appropriate PPE**, follow safety procedures and SOP's
- Never circumvent **Administrative or Engineering safety controls**
- Know the location and use of the **power kill switch and fire extinguisher**
- Use the buddy system when working with **high voltage equipment**
- **Not wear reflective metal jewelry** when working with laser beams
- **Never stare directly into a beam** even with eye protection; use indirect viewing
- Give sufficient attention to **non-beam hazards** to prevent possible injury and illness
- Be aware of **plasma and collateral radiation**
- **Notify supervisor immediately** of potentially hazardous conditions, personal injury, or property damage

IN EACH LAB, PERSONNEL MUST BE ABLE TO OBTAIN:

- **Training** on equipment, procedures and emergency procedures
- **Safety Equipment** that is sufficient in numbers for lab staff, appropriate for the equipment in use and in good operating condition
- **Standard Operational Procedures** for the safe use of all equipment
- Information from the PI or Lab Manager about **potential equipment hazards**

EMERGENCY INSTRUCTIONS

1. **Shut the laser off immediately** and **remove the interlock key**. If not possible, alert everyone to **exit the laboratory** and be the last to leave the laboratory

2. If there is a fire, get everyone out of the laboratory immediately. At the same time **shout "FIRE" loudly** and frequently. **Turn on a fire alarm**. Do not try to "fight" the fire from inside the laboratory; do it from the doorway to maintain an escape route

3. In the event of MAJOR injury, **Summon Medical Assistance.** Call 911 from a campus phone or 310-825-1491 from a cell phone

4. **Call Security and/or Fire Department (911) as necessary**

5. **Call EHS Hotline (59797) to report the incident**
   Note; ALL incidents must be reported to the Laser Safety Officer

6. **Contact the PI and/or Lab Manager** and describe the emergency

TABLE OF CONTENTS

Chapter 1:	**Introduction**	**…………………………..**	**1**
Chapter 2	**Scope and Responsibilities**	**…………………………..**	**3**
	2.1 Scope	………………………..	3
	2.2 Responsibilities	………………………..	3
	Personal, PI and Laser Operator Responsibilities	………………………..	4
	PI, Lab Manager and Supervisor Responsibilities	…………………………	5
Chapter 3:	**Work Practices Reference**	**…………………………..**	**7**
Chapter 4:	**Laser Light**	**…………………………..**	**9**
Chapter 5:	**Laser Classification**	**…………………………..**	**11**
Chapter 6:	**Laser Hazards and Injuries**	**…………………………..**	**13**
	6.1 Beam-Related Hazards	…………………………	13
	6.2 Non-Beam Hazards	…………………………	17
Chapter 7:	**Controls and Prevention**	**…………………………..**	**19**
	7.1 Engineered Controls	…………………………	21
	7.2 Administrative Controls	…………………………	23
	7.3 Standard Operating Procedures	…………………………	23
	7.4 Personal Protective Equipment	…………………………	24
	7.5 Beam Alignment	…………………………	25
Chapter 8:	**Emergency Procedures**	**…………………………..**	**27**

APPENDICES

		…………………………	29
Appendix A:	**Biological Effects of Laser Exposure**	**…………………………..**	**29**
	A.1 Beam Hazards Skin Hazards	…………………………	29
	Eye Hazards	…………………………	30
	A.2 Non-Beam Hazards	…………………………	31
Appendix B:	**Classification Table**	**…………………………..**	**33**
	CommonTypes of Laser	…………………………	33
Appendix C:	**Control Measures for Lasers**	**…………………………..**	**35**
Appendix D:	**Forms**	**…………………………..**	**37**
	Laser Eye Examination Form and Procedure	…………………………	37
	Laser Safety Self-Inspection Checklist	…………………………	38
	Laser Inspection Form	…………………………	41
	Laser Purchase Requisition Details	…………………………..	43
Appendix E:	**Inspection Criteria and Performance Expectations**	**…………………………..**	**45**
Appendix F:	**Injury Prevention and Controls**	**…………………………..**	**47**
	Engineered Controls	…………………………	47
	Administrative Controls	…………………………	53
Appendix G:	**Laser Anatomy**	**…………………………..**	**57**
Appendix H:	**Laser Pointer Safety**	**…………………………..**	**58**
Appendix I:	**Laser Safety Officers**	**…………………………..**	**59**
Appendix J:	**Personal Protective Equipment**	**…………………………..**	**61**
Appendix K:	**Responsibilities**	**…………………………..**	**63**
	Laser Safety Committee	…………………………	63
	Laser Safety Officer	…………………………	63
	Laser Safety Communication Structure	…………………………	64
Appendix L:	**Scope of Program**	**…………………………..**	**65**
Appendix M:	**Setting up a Laser Lab**	**…………………………..**	**66**
Appendix N:	**Standard Operating Procedures**	**…………………………..**	**67**
	Sample SOP's for Class 3B and Class 4 Lasers	…………………………	68
Appendix O:	**Suppliers of Laser Safety Products**	**…………………………..**	**77**
Appendix P:	**Glossary**	**…………………………..**	**79**

CHAPTER 1: INTRODUCTION

Lasers are devices that produce radiant energy by stimulated emission of light. Laser radiation is highly monochromatic, directional and coherent and can produce a beam of energy in the ultraviolet, visible, near infrared and far infrared regions of the electromagnetic spectrum. These beams pose unique and profound radiation hazards. As a consequence, laser usage must be carefully monitored to protect the health and safety of personnel and property within the greater University of California, Los Angeles (UCLA) campus community.

Environment Health and Safety (EH&S) recognizes that laser research is integral to the scientific community and strives to support UCLA's contribution to science by promoting safe laser practice. With this in mind, EH&S has prepared the Laser Safety Manual as a set of guidelines to promote safe laser operations at UCLA.

PURPOSE OF MANUAL

The purpose of this manual is to increase the necessary awareness of safe laser use in the UCLA working environment. It provides a view of the hazards associated with laser use, controls and procedures by which problems can be prevented and specifies national laser use standards where compliance is required when working with lasers.

This manual provides UCLA campus laser workers in research, education and training with guidance in the requirements and recommendations for Laser Safety that are specified in the American National Standards Institute (ANSI) standard Z136.1 - 2007. These are amplified by requirements specific to the UCLA campus.

The broad basic components of this manual include:

- **Responsibilities of laser users**
- **Classification of lasers**
- **Risks posed by lasers**
- **Controls and risk prevention**
- **Emergency procedures**

EH&S supports UCLA's contribution to science by promoting safe laser practice.
Laser operators must focus on procedures in a manner that supports and maintains the safety of the individual and the environment.

These components are further developed in the appendices to provide detailed information that includes:

- **Expanded information about most sections**
- **Laser Safety Vendor information**
- **Laser Safety Forms**
- **Information about setting up laser laboratories**

CHAPTER 2: SCOPE AND RESPONSIBILITIES

The requirements and recommended procedures contained in the Laser Safety Program are applicable to all individuals using lasers in the UCLA research, development, education and training community.

2.1 SCOPE

The EH&S Radiation Safety Division operates the Laser Safety Program which oversees campus laser operations. The Radiation Safety Officer or designee serves as the Laser Safety Officer (LSO) who is responsible for the implementation of safety standards and compliance with this manual.

This manual includes laws and regulations regarding laser usage that are outlined in California Division of Occupational Safety and Health (Cal/OSHA) regulations, in the ANSI standards handbook and in University Policies that must be followed when operating lasers devices on the UCLA campus.

Refer to **Appendix L: Scope of Program** for an expanded version of program scope.

2.2 RESPONSIBILITIES

Overview

In the most basic terms, **each worker has a personal responsibility** to perform and manage laser operations in a manner that prevents unsafe laser use.

While there are a range of hazards associated with laser use, the principal responsibility and objective of the laser worker remains:

AVOID GETTING A LASER BEAM IN YOUR EYE

If an action or process looks, feels or seems unsafe, **DON'T DO IT.**

Each worker must;

- Undergo **training** for specific equipment and labs
- Read and know **safe operating procedures**
- Respect and utilize **administrative and engineering controls**
- Always utilize appropriate **Personal Protective Equipment**

DON'T USE LASER EQUIPMENT without specific Training, Documents and Controls.

This allows laser safety to be exercised in a consistent and standardized way. Applying this same basic standard to workers around you and the labs in which you work will support safe laser operations at UCLA.

Personal Responsibilities

Program requirements and recommendations target the individual user, who has a primary responsibility to ensure personal safety in operational labs. However, the Principal Investigator (PI) is the responsible party within the lab for requiring laser training, defining lab operational requirements, authorizing the purchase of safety equipment and maintaining safe lab operations.

The premise of personal safety extends into the awareness of environmental safety (i.e. the safety of the specific lab and of those working with and around the individual), which is the essential to lab safety across the entire campus.

When you work, you should be asking yourself questions such as **'Am I working safely?'** and **'Would I be working that way?'** Self-evaluation is one method by which we can focus on safe and efficient performance when using lasers at UCLA. Statistically, most laser incidents are the result of operator error; **personal awareness and responsibility** are fundamental elements in avoiding laser incidents of all types.

As part of the laser user community it is **your obligation to correct or report unsafe actions or incidents.** Actions and incidents may be performed by you, observed by you or known to you that could impact campus laser operations. It is unacceptable to participate in any situation that may result in injury, damage, loss or harm to the individual, community or organization.

Laser Operator Responsibilities

Laser Operators are responsible for the safe operation of laser equipment, protection of themselves, workers in the vicinity, laser equipment and lab facilities.

Prior to working with a Class 3 or Class 4 lab laser or laser system, operators must:

1. Read the **Laser Safety Manual**
2. Complete:
   - **Initial laser safety training** and **refresher laser safety training** every 2 years
   - Equipment- and lab-specific **operational instruction**
3. Review:
   - Laboratory-specific laser **Standard Operating Procedures**
   - Equipment-specific **operating guides and safety instructions** furnished by the manufacturer
4. Observe all **operating safety rules**
5. Properly use all **prescribed Personal Protective Equipment (PPE)**, such as protective eyewear and sunblock, and safety devices, such as beam viewers, interlocks and beam stops.
6. **Notify their supervisor immediately** of potentially hazardous conditions, personal injury, or property damage

It is ***recommended*** that operators obtain a Laser Eye Examination through the Jules Stein Eye Institute (310-825-3090) before working with Class 3B or Class 4 Lasers.

Principle Investigator (PI), Laboratory Manager, and Supervisor Responsibilities

PI's, Laboratory Managers and Supervisors are responsible for;

- Development of a safe laser lab environment
- Development of documentation pertaining to lab equipment and procedures
- Training of all laser workers in the safe operation of laser equipment
- Approving personnel to operate lasers
- Providing adequate and appropriate Personal Protective Equipment
- Identifying and labeling all laser equipment
- Notifying EHS (x59797) and PI in the event of laser incident, accident or injury (Refer to **Emergency Procedures, page 26**)

Prior to allowing use of lasers PI's, Laboratory Managers, or Supervisors must:

1. Read the **Laser Safety Manual**
2. Prepare **written laser Standard Operating Procedures** and provide, implement, and enforce safety recommendations and requirements prescribed by the UCLA Laser Safety Program
3. **Provide hands-on laser training on specific equipment** to each laser user. Training must include routine procedures for safe operation, alignment procedures, emergency procedures, safety requirements and limitations of use
4. **Supervise laser use** and operations in the laboratory
5. **Classify and label all lasers** within their lab
6. **Complete all laser registration forms** and submit to the LSO
7. Ensure that laser operators and users have completed **EH&S Laser Safety Training** and refresher training every two years. Document specialized training of all employees who work with and around Class 3B and Class 4 lasers
8. Ensure that only **qualified and authorized personnel** are permitted to operate lasers. The PI determines the operational qualification of an employee from departmental or technical training or other acceptable learning experience
9. **Notify the EHS Hotline** (x59797) **and Occupational Health Facility** (OHF, 310-825-6771) immediately in the event of incidents involving injury or suspected injury from laser beam exposure (refer to **Emergency Procedures, page 26**). Employees reporting to OHF require appointments (if non-emergency) and a supervisor's referral slip
10. **Request EH&S review** of equipment design and laser safety procedures when fabricating new systems or making alterations of existing systems
11. **Ensure that lasers built "in house" meet the criteria of applicable standards** including ANSI Z136.1-2007 and 21 Code of Federal Regulations (CFR), pt 1040. Lasers must be evaluated by EH&S, appropriately classified and labeled

It is recommended that PI's, Laboratory Managers, or Supervisor's have all personnel who are scheduled to work with Class 3B or Class 4 lasers obtain a Laser Eye Examination at the Jules Stein Eye Institute (310-825-3090) before beginning use.

Refer to **Appendix K: Responsibilities** for details of Laser Safety Officer and Laser Safety Committee responsibilities and the Laser Safety Communication Structure.

CHAPTER 3: WORK PRACTICES REFERENCE

For Class 3B and Class 4 lasers and laser systems, the following operational work practices must be met:

- **WARNING SIGNS**: Appropriate warning signs must be posted at each lab entryway. These specify the type and class of laser and special precautionary instructions
- **TRAINING**: The laser must be operated only by personnel who have been appropriately trained in laser safety and in the specific laser procedures to be performed. **All laser operators must be authorized by the Principal Investigator to operate the laser and perform the work**
- **BEAM POSITIONING**: Laser beams must always be positioned above or below the normal eye level of a standing or sitting person
- **BEAM TERMINATION**: The laser must have any potentially hazardous beam terminated in a beam stop of an appropriate material
- **REFLECTIVE MATERIALS**: The laser must have only diffusely reflecting materials in or near the beam path, where feasible. **Avoid wearing metal jewelry** (wristwatches in particular) while working with laser beams
- **WEAR EYE PROTECTION**: Eye protection must be worn when Class 3B or Class 4 lasers are operated in a manner that is possible to allow eyes to be exposed to hazardous levels of direct or reflected laser radiation
- **ENGINEERING CONTROLS**: Engineering controls (interlocks, beam stops, signs, activation warning systems, etc.) are the first line of defense against laser hazards and must always be utilized. **Control measures must not be defeated unless the operator is following a specific Standard Operating Procedure**
- **SUPERVISION**: The laser must be under the direct supervision of an individual knowledgeable in laser safety
- **BEAM TRANSMISSION**: Windows and doorways must be covered or restricted in a manner to reduce transmitted laser radiation below the Maximum Permissible Exposure
- **OPTICAL DEVICES**: Optical devices may concentrate the amount of laser light arriving at the eye. When using an optical viewing device, ensure that the viewer does not directly view the beam or specular reflection. Microscopes used in laser work must be supplied with an attenuation filter
- **SPECTATOR ACCESS**: Lasers must be located so that access by spectators is limited. It is best to exclude visitors from labs in which Class 3B and Class 4 lasers are in use

- **ACTIVATED EQUIPMENT**: An activated laser must not be left unattended without appropriate safeguards such as illuminated warning signs, blackout curtains and door interlocks where applicable

- **EQUIPMENT DISABLE**: The laser or laser system should be disabled by means of a key when not in use, to prevent use by untrained operators

- **CONTROLLED AREA**: Lasers should be surrounded by light absorbing curtains or other appropriate light-blocking measures; these barriers, screens, curtains, etc., must also be fire-resistant

- **ENTRYWAY CONTROLS**: Class 4 lasers must have a system for entryway safety controls such as a doorway interlock mechanism

- **EYE PROTECTION SUPPLIES**: Personnel must be provided with appropriate eye protection in good operating condition. Protective eyewear must be manufactured and labeled for specific laser use, compatible with laser wavelengths, marked with appropriate the Optical Density and wavelength(s) and must pass enough visible light so that experiments can be conducted safely

- **SECURE EQUIPMENT**: Properly secure lasers and optical components used with them to the table to avoid eye injuries due to inadvertent movement of the items during experiments

- **VIEWING BEAM**: Never stare directly into a laser beam, regardless of class, even if eye protection is worn. Use an indirect means (beam card, photodetector, etc.) to observe the beam

- **LIGHT SOURCE SHIELD**: A shield should be provided around light sources used to pump lasers to prevent injury from flying glass in the event of a light source explosion

- **POWER SUPPLY**: When accessing the power supply or other high voltage electrical equipment always utilize the buddy system. Personnel assisting with repairing, maintaining or replacing this equipment should be trained in cardiopulmonary resuscitation (CPR)

- **NON-BEAM HAZARDS**: Pay sufficient attention to non-beam hazards to prevent resulting injuries and illnesses

  Refer to **Appendix A: Biological Effects of Laser Exposure; Non-Beam Hazards** for further details of Non-Beam Hazards

CHAPTER 4: LASER LIGHT

In Laser Labs we are more concerned with the wavelength and power of the light that is emitted from a laser (the beam) than we are about how it is created. The type of laser is important in determining what associated hazards there might be, but ultimately, if there is an exposed beam, a potential hazard exists.

Why is Laser Light Harmful?

Laser light is created by **STIMULATED PHOTON EMISSION** (LASER is an acronym for ***Light Amplification by Stimulated Emission of Radiation***).

Unlike normal light (produced by spontaneous photon emission), the photons in laser light are;

- **Monochromatic** (i.e. photons all have substantially one wavelength)
- **Directional** (i.e. photons all travel in the same direction).
- **Coherent** (i.e. photons are all in the same phase)

The characteristics of laser light allow for:

- **Low divergence**, so the beam spreads or scatters very little and maintains intensity over long distances
- **High irradiance**, so the beam is very bright and can focus intense energy on a small area

Lasers:

- Are the brightest light sources known
- Can produce significant eye hazards at relatively low energy levels
- Can be concentrated to an even higher intensity when focused by a lens (such as eyeglasses)
- Can be operated in pulsed mode to further increase power output

Lasers light generates heat and extremely focused brilliant light that will typically produce enormous biological impact on the eyes.

Lasers operate in the 200 nanometer (nm) – 10,000+ nm range, which extends well below and above the visible light spectrum (~ 400 nm – ~ 700 nm). Many lasers produce light that is invisible to the human eye; in the event of an exposure, the aversion response (blink reaction ~0.25 secs) provides no protection to the viewer.

Refer to **Appendix G: Laser Anatomy** for further information on how laser light is generated.

CHAPTER 5: LASER CLASSIFICATION

Lasers and laser systems are grouped according to their **capacity to produce biological injury to the eye or skin** and laser classifications are specified in the ANSI Z136.1-2007 standard. A laser classification is an indication of the beam hazard during normal operation and is defined by the hazard potential of the accessible beam.

The hazard classification of a laser or laser system is represented by a number/letter combination; the higher the classification number, generally the greater the hazard and the more precautions are required.

All manufacturers have been required to classify and label all lasers produced since August 1, 1976. Information on the label must include laser class, the maximum output power, the pulsed duration (if pulsed), and the laser medium or emitted wavelengths.

ANSI modified the standard for laser classification in 2007; models purchased earlier may still display older classification numbers, which must be updated. The current laser classifications are Class 1, Class 1M, Class 2, Class 2M, Class 3R, Class 3B, and Class 4.

The following chart indicates the recent broad reclassification of lasers;

Previous ANSI Standard Hazard Classes	New Hazard Classes ANSI Z136.1-2007
I	1/1M*
II	2/2M*
IIa (most laser pointers)	2
IIIa(expanded-beam lasers)	3R^
IIIb	3B
IV	4

*M: Magnification

^R: Reduced or Relaxed Requirements.

Specific controls are described for each laser classification.

Refer to **Appendix B: Classification Table** for a list of common types of lasers used at UCLA.

Lasers are generally classified and controlled according to the following criteria:

Class 1

Laser systems that **cannot emit laser radiation levels greater than the Maximum Permissible Exposure** (refer to **Appendix P: Glossary, MPE**) and are considered to be incapable of causing eye damage under normal operating or viewing conditions

- **Maximum power output; a few microwatts**
- Higher class lasers may be fully embedded in Class 1 devices to enclose the beam path. Such lasers require extreme caution if the beam enclosure is opened for any reason (maintenance, trouble-shooting, repair, alignment, etc.)

Class 1M

Laser systems **considered incapable of producing hazardous exposure conditions during normal operation** unless the beam is viewed with an optical instruments, such as eye-loupes (diverging beam) or telescopes (collimated beam).

Class 2 and Class 2M

Visible, low power laser systems **considered incapable of causing eye damage unless they are viewed directly for an extended period** (greater than 1000 secs) or with certain optical aids.

- Emit light in the visible portion of the spectrum (400 nm – 700 nm)
- **Maximum power output; < 1mW**
- Normal human aversion response will usually prevent exposure

Class 3R

Medium-power laser systems that may be hazardous under direct and reflected beam viewing conditions, but do not pose a diffuse reflection or fire hazard. These are not normally hazardous if viewed for only momentary periods with the unprotected eye.

- **Maximum power output; 1 mW – < 5 mW**
- Generally no eye damage with short duration exposure < 0.25 sec. (blink response)
- Visible and invisible (UV, IR) wavelengths
- Dangerous if viewed with magnifying optics (including eyeglasses)

Class 3B

Higher-power laser systems capable of producing a hazard from direct and reflected beams but rarely from diffusely reflecting surfaces (e.g. painted walls, white paper, etc.).

- **Maximum power output; 5 mW - 500 mW**
- Aversion response is no protection
- Visible and invisible (UV, IR) wavelengths
- May be pulsed; potentially lethal high voltage supply

Class 4

High-power laser systems always capable of producing a hazard to the eye or skin

- **Maximum power output; > 500 mW**
- Direct, Specular and Diffuse Reflection can cause severe eye and skin damage
- Aversion response is no protection
- Fire hazard
- May be pulsed; potentially lethal high voltage supply

CHAPTER 6: LASER HAZARDS AND INJURIES

BIOLOGICAL EFFECTS OF LASER EXPOSURE

The hazards associated with lasers can be separated into two categories:

- **BEAM-RELATED HAZARDS** (occurring as a direct result of worker/beam interaction), which are typically caused because by **LIGHT AND HEAT**

- **NON-BEAM HAZARDS** (caused as a result of indirect beam/target interaction or as a direct result of the properties of laser equipment). Hazards are not limited to the following, but these are key areas for consideration;
  - **Electrical shock and fire hazards**
  - **Explosion and fire from compressed gases and solvents**
  - **Carcinogenic properties of laser dyes**
  - **Contaminants generated from a plume**
  - **Collateral and plasma radiation**

Biological effects may be;

- **Acute** - involving substantial exposure over a short period of time (burns)
- **Chronic** – involving low exposures over a long period of time (cancer)

6.1 BEAM-RELATED HAZARDS

EYE INJURY

The most common injuries relate to eyes; the output of lasers is light and the eye is the organ that is most sensitive to light. Laser-produced eye injuries tend to be acute and catastrophic; all laser eye injuries are preventable.

Types of damage that eye hazards can cause are:

- **Photochemical -** light exposure triggering chemical reactions in tissue and breaking or forming molecular bonds. Photochemical damage occurs mostly with short-wavelength (blue) and ultra-violet light and can be accumulated over a period of time. Cataracts are an example of photochemical damage
- **Thermal -** the absorption of laser radiation causing a temperature rise in tissue to the point where denaturation of proteins occurs. Retinal burns are an example of thermal damage. A transient temperature increase of only 10 °C can destroy retinal photoreceptors
- **Acoustic** - A rapid raise in temperature may result in explosive boiling of vitreous humor causing mechanical shockwaves through tissues as the water evaporates to steam. The shock wave from the explosion can subsequently cause damage relatively far away from the point of impact. Hemorrhaging and bleeding are examples of acoustic damage that may be caused from exposure to pulsed lasers

The dependency factors for eye damage are:

- **Length of exposure** – power must be taken into account; a long continuous wave low-level exposure may do much less damage than a short pulsed laser exposure
- **Energy** – power of source
- **Wavelength** – Determines which part of the eye absorbs the radiation and if radiation is focused by the eye onto the retina

Wavelength	Area of Damage	Pathological Effect
180-315 nm (Ultraviolet UV-B, UV-C)	**Cornea** - deep-ultraviolet light causes accumulating damage, even at very low powers	Photokeratitis (inflammation of the cornea, similar to sunburn)
315-400 nm (Ultraviolet UV-A)	**Cornea and Lens**	Photochemical cataract (clouding of the lens)
400 -780 nm (Visible)	**Retina** - Visible light is focused on the retina	Photochemical damage to retina and retinal burns
780 -1400 nm (Near Infrared)	**Retina** - Near IR light is not absorbed by iris and is focused on the retina	Thermal damage to cataract and retinal burns
1400 -3000 nm (Infrared)	**Cornea and Lens** – IR light is absorbed by transparent parts of the eye before reaching the retina	Aqueous flare (protein in aqueous humor), cataract, corneal burn
3000 – 10000 nm (Far Infrared)	**Cornea**	Corneal burn

- **Location of exposure** – The macula and fovea provide for visual acuity and damage to these areas is likely to be catastrophic and permanent

Other Factors

When exposure occurs, the light range may not be visible and **the brain may compensate for eye injury**, leaving **the worker unaware of any damage**. Near IR radiation light, for example, is almost invisible to the human eye and because we don't see the light, our aversion response doesn't function.
Exposure to a high power Nd:YAG laser emitting invisible 1064 nm radiation may be painless and victims may not immediately notice any vision damage. A pop or click sound from the eyeball may be the only indication that retinal damage has occurred (caused by the retina heating to over 100 °C resulting in localized explosive boiling accompanied by the immediate creation of a permanent blind spot).

Multiple and compound injuries, such as cataracts, retinal burns, bleeding, blind spots and permanent loss of vision, **can occur throughout the eye and at all wavelengths**; lasers with higher wavelengths generally pose greater risks.
Areas of the eye that are most vulnerable to damage are:

- **Retina**, the membrane lining the back of the eye that contains photoreceptor nerve cells which react to the presence and intensity of light
- **Fovea**, a 3-4% section of the retina in the center of the macula that provides for the most detailed and acute vision

RETINA

- The most important element of the eye
- Retina is 0.55 mm thick and easily damaged
- Contains the rods and cones, photoreceptors that are responsible for visual abilities such as day, night, color and peripheral vision and visual acuity
- **Visible and near-IR laser light damage**

– Retinal sunburn may result from exposure to argon laser blue light (400 - 550 nm)
– Retinal burns / detachment may occur in the Retinal Hazard Region (400 -1400 nm)
– Laser strikes to the retina may create blind spots; repeated retinal burns can lead to blindness.

FOVEA

- The majority of cones are situated in the fovea
- Acute vision may be lost instantaneously if a laser burn occurs in the fovea
- **Near IR laser light** is not absorbed strongly by the iris and focuses on the fovea

SKIN INJURY

Skin hazards occur at all wavelengths of laser light, although the impact is less dramatic than the hazards posed to eyes. Skin injuries tend to be chronic in nature.

The dependency factors for skin damage are;

- **Time** - thermal reactions usually cause tissue proteins to denature when exposure times exceed 10 microseconds
- **Wavelength** - laser light can be reflected or absorbed by various layers of skin
  - Most radiation is absorbed by the outer 4mm of the skin
  - 10,600 nm wavelengths (CO_2, far infrared) are well absorbed by skin and cause surface burns
  - 1000 nm wavelengths (Nd-YAG) are not absorbed well by skin and result in deep tissue burns similar to an electric burn

The types of biological injuries that can occur to the skin are:

- **Skin burns** –significant burns may occur from acute exposure to wavelengths of 300 – 10000 nm
- **Skin Cancer** – may be caused by chronic exposure to low levels or scatter radiation of UV-C at 200 – 280 nm. This light is not absorbed well by materials and may also cause erythema (sunburn) and accelerated skin aging

6.2 NON-BEAM HAZARDS

The nature of non-beam hazards may be;

- **Chemical**
- **Biological**
- **Physical**
- **Ergonomic**

Typical non-beam biological hazards involve;

- **Electrical** (shock, fire)
- **Gases, Solvents** (explosions, fire)
- **Dyes** (toxicity, carcinogens)
- **Plumes** (biochemical dispersion)

In the research environment, users must be aware of **electrical hazards** from large power sources and power supply conductors operating at potentials in excess of 50 volts and electrical components such as capacitors, equipment grounding and exposed energized parts. There may be issues related to **Laser Generated Air Contaminants** (LGAC's) that can develop within the **laser plume** as a result of burning, vaporisation or ablation of material.

The most prevalent hazards in the laser laboratory relate to the use of compressed gases, solvents and dyes.

Compressed Gases may be;

- Simple **Asphyxiants** (dilutes or displaces the oxygen containing atmosphere, leading to death by asphyxiation)
- **Toxic with a low Threshold Limit Value** (TLV), which is the amount of concentration in air of a substance permitted for a worker for a working lifetime without adverse health effects

Dye Lasers

- Fluorescent organic compounds form lasing medium, typically suspended in flammable solvents such as ethanol and methanol
- Process uses and produces both carcinogens and toxins. Powdered dyes are know carcinogens and must be handled with extreme care (use gloves and double bagging)
- Most dyes also exhibit unknown mutagenicity (DNA mutation) characteristics

Refer to **Appendix A: Biological Effects of Laser Exposure** for more detailed examples of eye anatomy, eye injuries, biological effects of exposure and physical hazards caused by lasers.

CHAPTER 7: CONTROLS AND PREVENTION

To help maintain a safe laser environment, required and recommended controls in the ANSI Z136.1- 2007 standard include;

- **Engineering Controls** – that address the physical environment in which the laser is operating
- **Administrative Controls** – that address operational requirements during laser use

Personal Protective Equipment (PPE) *is an Administrative control that is NOT the primary means of protection. If PPE was the only method of protection and it failed, exposure would certainly result. PPE is always the backup for other Engineering and Administrative controls, but must never replace them or be used without them.*

Laser use will always involve a combination of Engineering and Administrative controls. All administrative, procedural, and engineered safety control measures must be consistently applied when operating a laser laboratory. Required controls must not be ignored or defeated and recommended controls should always be seriously considered.

Based on a laser hazard evaluation that must be completed by the LSO, the LSO may approve controls that deviate from those listed in the ANSI standard to obtain equivalent laser safety protection when specified engineered controls are not feasible or are inappropriate. Alternative controls and procedural substitutions may include;

- Specifically written Standard Operating Procedures
- Operating a Class 3B or 4 laser with a fully open beam path
- Completely enclosing high power lasers to bring them to Class 1 specifications

Certain requirements apply to all laser use;

- **All users must receive training and instruction**, including
  - EHS laser training
  - Lab- / Equipment-specific operational training
  - EHS refresher training
- **All lasers must have a protective housing** (an enclosure surrounding the laser or laser system that limits access to electrical hazards associated with internal components and radiant energy. The useful beam emits from this protective housing)
- **All lasers must be clearly labeled** with the Class and type and an appropriate warning label

It is recommended that all laser users complete a Laser Eye Examination at the Jules Stein Eye Clinic prior to using and after completing use of any lasers at UCLA.

The following tables indicate the ANSI Standard Engineered and Administrative control requirements and recommendations for laser use at UCLA. Note that the requirements for Class 3 and Class 4 lasers are far greater than those for Class 1 and Class 2 equipment, indicating the increased hazards associated with their use.

7.1 ENGINEERED CONTROLS

ANSI ENGINEERING CONTROL MEASURES

Engineering Control	CLASS I/IM	CLASS 2/2M	CLASS 3R	CLASS 3B	CLASS 4
Protective Housing **4.3.1**	REQUIRED	REQUIRED	REQUIRED	REQUIRED	REQUIRED
Interlocks; Removable Protective Housing **4.3.2**	Required if enclosed 3B/4	Required if enclosed 3B/4	Required if enclosed 3B/4	REQUIRED	REQUIRED
Service Access Panel **4.3.3**	Required if enclosed 3B/4	Required if enclosed 3B/4	Required if enclosed 3B/4	REQUIRED	REQUIRED
Key Control **4.3.4**				Recommended	REQUIRED
Fully Open Beam Path **4.3.6.1**				REQUIRED	REQUIRED
Limited Open Beam Path **4.3.6.2**				REQUIRED	REQUIRED
Remote Interlock Connector **4.3.7**				Recommended	REQUIRED
Beam Stop or Attenuator **4.3.8**				Recommended	REQUIRED
Activation Warning Systems **4.3.9.4**				Recommended	REQUIRED
Indoor Laser Controlled Area **4.3.10**	Recommended M	Recommended M		REQUIRED	REQUIRED
Temporary Laser Controlled Area **4.3.12**	Required if enclosed 3B/4	Required if enclosed 3B/4	Required if enclosed 3B/4		
Controlled Operation **4.3.13**					Recommended
Equipment Labels **4.3.14 & 4.7**	REQUIRED	REQUIRED	REQUIRED	REQUIRED	REQUIRED
Area Warning Sign and Activation Warning **4.3.9**			Recommended	REQUIRED	REQUIRED

In addition to ANSI Engineering controls, the following **GENERAL ENGINEERING CONTROLS** are exercised on the UCLA campus**;**

- **Lighting** must be sufficient to support identification of equipment, laser controls and emergency egress during normal use in controlled areas. Class 4 laser controlled areas must display an indicator outside the entrance that is lit when the laser is in operation

- **Ventilation** (gas cabinet) must be provided in labs using fluorine or hydrogen fluoride as an excitation medium in an excimer laser system. If a gas cabinet is unavailable, fluorine gas must be contained in a functional fume hood or equivalent

- **Electrical Hazards,** particularly shock, can occur when equipment protective covers are removed and controls must be implemented to prevent electrical accidents. Typical controls include labeling shielding, grounding, lock-out/tag-out, etc.

- **Flammability Hazards** occur from the ignition of fuel sources, such as curtains and room furnishings and increase when flammable gases are present. Curtains and barriers must be

- made from nonflammable material and flammable gases and solvents must be isolated from potential ignition sources

- **Chemical Hazards** include solvents and laser dyes, which must be treated as Hazardous Chemicals. Dyes require special care when handling, including preparation of solutions and operation of the laser. Solvents can be flammable and toxic by inhalation or skin absorption. Controls include leak testing of the dye containment system, secondary containment for storage and waste and PPE.

- **Optical Devices** may concentrate the amount of laser light at the eye and controls must ensure that the operator does not view the beam or a specular reflection directly with the optical device. Microscopes used in laser work should be provided with an attenuation filter.

Refer to **Appendix F: Injury Prevention and Controls; Engineered Controls** for more detailed information about laser lab Engineering Control requirements.

7.2 ADMINISTRATIVE CONTROLS

ANSI ADMINISTRATIVE CONTROL MEASURES

Administrative Control	CLASS I/IM	CLASS 2/2M	CLASS 3R	CLASS 3B	CLASS 4
Standard Operating Procedures 4.4.1				Recommended	REQUIRED
Education and Training 4.4.3		Recommended	Recommended	REQUIRED	REQUIRED
Authorized Personnel 4.4.4				REQUIRED	REQUIRED
Alignment Procedures 4.4.5	**Required if enclosed 3B/4**	**Required if enclosed 3B/4**	**Required if enclosed 3B/4**	REQUIRED	REQUIRED
Protective Equipment 4.6				Recommended	REQUIRED
Spectator Control 4.4.6				Recommended	REQUIRED
Specified Service Personnel 4.4.7	**Required if enclosed 3B/4**	**Required if enclosed 3B/4**	**Required if enclosed 3B/4**	REQUIRED	REQUIRED
Protective Eyewear 4.6.2				REQUIRED	REQUIRED
Window Protection 4.6.3				REQUIRED	REQUIRED
Protective Barriers and Curtains 4.6.4				Recommended	Recommended
Skin Protection 4.6.6				REQUIRED for UV excimers	REQUIRED for UV excimers
Warning Signs and Labels 4.7		Recommended	Recommended	REQUIRED	REQUIRED
Eye Examination 6.2				Recommended	Recommended

The LSO may allow alternate methods to achieve equivalent laser safety protection by administrative controls when engineering controls are inappropriate. This may be accomplished by specific Standard Operating Procedures where each SOP is reviewed and approved by the Laser Safety Office prior to being adopted for use. These adjustments typically apply to Class 3B and Class 4 lasers.

In addition to the required and recommended ANSI Administrative controls, the following **GENERAL ADMINISTRATIVE CONTROLS** must be exercised on campus;

- **Laser Purchase Review** must be conducted by EH&S prior to the purchase of a new laser or essential laser components. The purpose is to incorporate the new laser into the inventory system and to specify any special precautions or requirements for use
- **Authorized Access** must be controlled for labs solely used for lasers or laser systems. Only personnel authorized by the PI or Lab manager are allowed access. Non laser-only labs must initiate precautions to prevent unauthorized access to laser areas.

Refer to **Appendix F: Injury Prevention and Controls; Administrative Controls** for more detailed information about laser lab Administrative Control requirements.

7.3 STANDARD OPERATING PROCEDURES

Written Standard Operating Procedures (SOP's) must constitute a comprehensive guide to the features, functions and use of laser equipment in the lab. SOP's must address beam and non-beam hazards and should be available for immediate reference. SOP's will include;

- **Operating Procedures, Requirements and Restrictions for each device**
- **Hazard Information of each device and PPE requirements**
- **Alignment Procedures**
- **Personnel Access Limits** while the laser is in use
- **Medical Surveillance and Eye Examination Recommendations** as applicable
- **Outdoor Use and Demonstration requirements** as applicable

Refer to **Appendix N: Standard Operating Procedures** for more detailed information about laser lab SOP requirements and to view a sample SOP.

7.4 PERSONAL PROTECTIVE EQUIPMENT (PPE)

Certain types of Personal Protective Equipment are required when working with lasers. **PPE is never a substitute for common sense and the use of good safety practices**

Eye Protection is important and required because the eye is susceptible to serious damage from laser light. Protective eyewear can be goggles, face-shield or glasses and must be specifically suited to the wavelength and power of the laser in use.

Before protective eyewear is used, it must be checked for defects and to verify it is suitable for the wavelengths of lasers in use. **Damaged or unsuitable eyewear must be discarded and replaced.**

Laser Protective Eyewear;

- Must be an appropriate safeguard, be available, in good condition and in sufficient quantities for all workers
- Is not the primary line of defense
- Is required to meet **ANSI Z87.1 standards** for Class 3 and Class 4 lasers
- Must be marked with **Optical Density and Wavelength**
- Needs must be **reassessed when new personnel, equipment or processes are introduced to the lab**

Skin Protection; Bare skin may require cover to prevent acute exposure to high levels of laser radiation that may cause skin burns or chronic exposure to UV wavelengths (295 nm – 400 nm) that can result in sunburn, pigmentation change and skin cancer.

- **Appropriate skin protection is required for Class 3B or 4 laser use;** Skin protection can include gloves, lab coat, sun block, skin cream and possibly a face-shield

Refer to **Appendix J: Personal Protective Equipment** for more detailed information about laser lab PPE.

7.5 BEAM ALIGNMENT

Alignment is the process that demands the greatest attention to safety because, **a**ccording to the most recent figures;

- **73% of all reported laser injuries are eye-related**
- **35% of eye-related injuries were associated with the alignment process**
- **68% of eye-related injuries result in permanent injury**

Because of excessive eye hazards during beam alignment, it must be performed in a manner that ensures that the eye is not exposed to light above the applicable MPE from the primary beam or specular or diffuse reflection of the beam.

The group that normally uses the laser must write the alignment procedure, which must include the vendor (if alignment is performed by a qualified vendor) and the frequency of alignment.

When performing alignments, always;

- **Review and follow written Alignment procedures**
- **Use Laser Alignment eyewear**
  NEVER REMOVE SAFETY EYEWEAR DURING THE ALIGNMENT PROCESS
  If you cannot see the beam with the eyewear you are using, your eyewear is the wrong Optical Density. Turn off the laser and obtain eyewear with the correct Optical Density.
- **Use alignment aids**
  - **IR and UV cards that glow in the visible range**
  - **IR viewers**

  DON'T LOWER THE LIGHTS TO SEE THE BEAM BETTER!!!
- **Use the laser at reduced power or substitute low power lasers to trace and check the beam path**
- **Use beam blocks at each beam section to reduce potential for stray light**
- **Check for stray light before completing alignment and increasing power**

-

CHAPTER 8: EMERGENCY PROCEDURES

In the event of a laser incident that involves non-routine operating events, immediately do the following;

7. **Shut the laser off** and **remove the interlock key**

8. In the event of a fire
   Alert everyone to exit the laboratory and be the last to leave.
   Shout 'FIRE' loudly and frequently.
   Turn on a fire alarm.
   Do not try to fight the fire from inside the room; do it from a doorway so that you have a means of escape.

9. In the event of MAJOR injury

   Summon Medical Assistance

   Call 911 from a campus phone or 310-825-1491 from a cell phone

   In the event of MINOR injury and party can walk without increased injury, direct party to:

   WORKING HOURS

   Students: Ashe Student Health and Wellness Center, **x54073.**
   Located on the north side of Bruin Plaza
   Open M-F 8:00 a.m. – 5:00 p.m.

   Employees: Occupational Health Facility, **x56771.**
   Located at 10833, Le Conte Avenue**.**
   Open M-F 7:30 a.m. – 4:00 p.m.

   AFTER HOURS

   All Personnel: UCLA Reagan Emergency Medical Center, **x52111.**
   Located at Charles E. Young Drive and Gayley Ave.
   Open daily 24 hours.

10. **Call Security and/or Fire Department (911) as necessary**

11. **Obtain contact information from witnesses and/or personnel in the area** as required

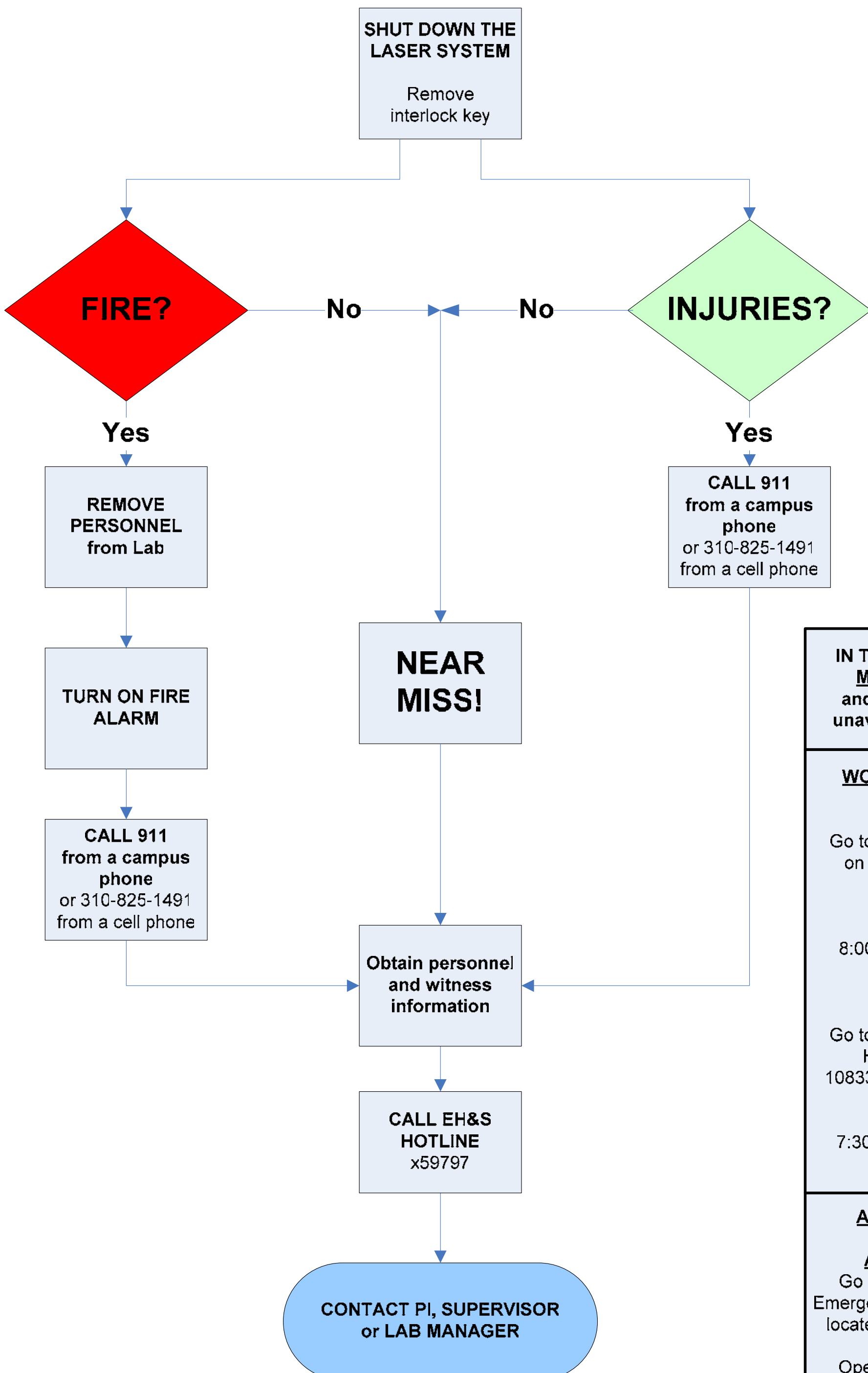
12. **Call EHS Hotline (59797) to report the incident**
    Note; ALL incidents must be reported to the Laser Safety Officer

13. **Contact the PI and/or Lab Manager** and describe the emergency

EMERGENCY PROCEDURES

IN THE EVENT OF A LASER INCIDENT, DO THE FOLLOWING <u>IMMEDIATELY</u>

Note; ALL INCIDENTS MUST BE REPORTED TO THE LASER SAFETY OFFICER



IN THE EVENT OF A <u>MINOR INJURY</u> and if assistance is unavailable from 911

<u>WORKING HOURS</u>

<u>Students</u>:
Go to the Ashe Center, on the north side of Bruin Plaza

Open M-F, 8:00 a.m. – 5:00 p.m
x54073

<u>Employees</u>:
Go to the Occupational Health Facility, 10833 Le Conte Avenue

Open M-F 7:30 a.m. – 4:00 p.m.,
x56771

<u>AFTER HOURS</u>

<u>All Personnel</u>
Go to UCLA Reagan Emergency Medical Center located off Gayley Ave.,

Open 24 hours daily,
x52111

APPENDICES

APPENDIX A: BIOLOGICAL EFFECTS OF LASER EXPOSURE

BEAM-RELATED HAZARDS

Skin Hazards

Types of biological injuries that can occur to the skin are:

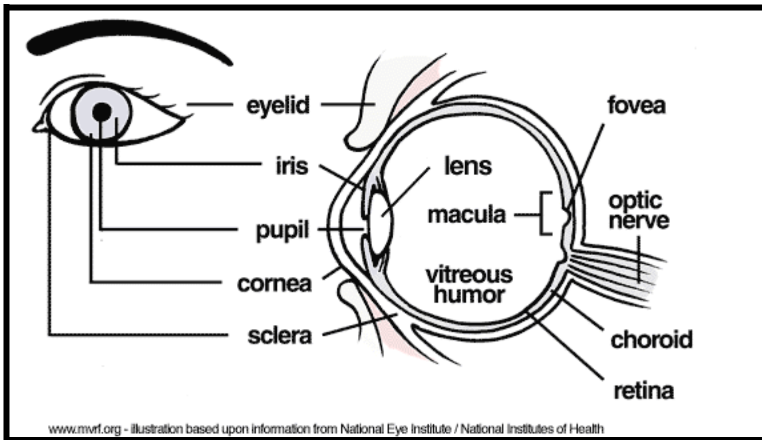
- **Skin burns** – **Acute exposure** may cause significant burns (300 – 10000 nm)
- **Pigmentation changes – Chronic exposure** causes photochemical reactions (common in Mid UV 280 – 780 nm)
- **Skin Cancer** –**Chronic exposure** to low levels or scatter radiation of UV-C at 200 – 280 nm. May also cause erythema (sunburn) and accelerated skin aging

Summary of Laser Biological Effects		
Photobiological Spectral Domain	**Eye Effects**	**Skin Effects**
Ultraviolet C (200 nm-280 nm)	Photokeratitis	Erythema (sunburn) Skin cancer Accelerated skin aging
Ultraviolet B (280 nm-315 nm)	Photokeratitis	Increased pigmentation
Ultraviolet A (315 nm-400 nm)	Photochemical cataract	Pigment darkening Skin burn
Visible (400 nm-780 nm)	Photochemical and thermal retinal injury	Pigment darkening Photosensitive reactions Skin burn
Infrared A (780 nm -1400 nm)	Cataract and retinal burn	Skin burn
Infrared B (1.4µm-3.0 µm)	Corneal burn Aqueous flare Cataract	Skin burn
Infrared C (3.0 µm-1000 µm)	Corneal burn only	Skin burn

EYE HAZARDS

ANATOMY OF THE EYE

It is useful to understand how the human eye works to appreciate the risks that lasers pose.



Cross section of the human eye.

CORNEA

- The transparent, outermost layers of the eye that transmit and focus light
- 70% of the refractive power of the eye
- Damage to the cornea or epithelium (cover) layer may feel painful, gritty and uncomfortable, but will typically heal quickly in between 48 hours and one week
- Damage to the deeper layers of the cornea may cause permanent injury
- **Mid and Far IR laser light can create corneal burns**

LENS

- The transparent structure behind the cornea that focuses light onto retina
- Lens brings objects into focus; hardening or damage decreases clear vision
- 30% of refractive power of the eye
- **Mid and Far IR laser light can create cataracts**

RETINA

- The membrane lining the back of the eye that contains photoreceptor nerve cells, which react to the presence and intensity of light
- The most important element of the eye, it is an extension of the brain
- Retina is 0.55 mm thick and easily damaged
- Contains the rods and cones that are responsible for visual abilities such as day, night, color and peripheral vision and visual acuity
- **Visible and near-IR laser light**

– Retinal sunburn may result from exposure to argon laser blue light (400 - 550 nm)
– Retinal burns / detachment may occur in the Retinal Hazard Region (400 -1400 nm)
– Retinal laser strikes may create blind spots; repeated burns can lead to blindness.

FOVEA

- The majority of cones are situated in the fovea (center of the macula) which comprises 3-4% of the retina and provides the most detailed and acute vision
- Acute vision may be lost instantaneously if a laser burn occurs in the fovea
- **Near IR laser light** is not absorbed strongly by the iris and focuses on the fovea

NON-BEAM HAZARDS

Lasers hazards are not limited to the direct interaction between the beam and the human body. Additional hazards are present and must be appreciated and considered when operating laser systems.

Non-beam hazards are caused as a result of indirect target/beam interaction or as a result of the electrical, chemical, physical, etc., properties of laser equipment.
While hazards are not limited to the following list, the following are key areas to remember when reviewing potential laser hazards

- **Electrical hazards**
- **Fire hazards**
- **Compressed gases and solvents**
- **Laser dyes**
- **Contaminants generated from a plume**
- **Collateral and plasma radiation**

Electrical Hazards

- High voltage laser components
- Contact with exposed, energized conductor or carrier
- Completion of electrical circuit through individual
- Environmental factors - standing water, poor visibility, crowded work areas, untrained personnel
- Incidents generally occur during installation, repair or maintenance

Fire and Explosion Hazards

- Often related to electrical hazards
- Laser energy (ignition source) contacts concentrated flammable materials (including solvents, gases)
- Laser energy contacts gas under pressure
- Static charge or spark ignites fire

Chemical Hazards

- Dye Laser dyes must be treated as hazardous chemicals
- Laser Generated Air Contaminants (LGAC's, laser plumes)
- Formed by interaction between laser beam and material processed ; the chemical debris, products of pyrolysis
- Power of beam determines severity of air contaminant
- Can be in form of aerosols, gases, vapors
- Aerosols differ in composition, size, toxicity, but most are small and can be breathed into the lungs
- Typically, but not limited to Medical laser use
- May involve Infectious Materials, Bloodborne Pathogens (viral and bacterial), Organic material (including aliphatics, aromatics, oxides and Inorganic material (such as oxides of base metals).

Dye Laser Hazards

- Dye Laser dyes, solvents and the products of dye lasers are toxic or carginogenic
- Personnel must use Personal Protective Equipment that is appropriate for eye, skin and inhalation protection when working with dyes
- All stored dye stocks and waste must be double-bagged for spill protection
- Precautions must be taken when handling dyes, including preparation of dye solutions and operation of dye lasers
- Laser dye solutions should be prepared inside a chemical fume hood
- Dye laser components should be leak tested before using dye solutions. All tubing must be securely fastened or clamped
- Spill pans should be installed under pumps and reservoirs
- Material Safety Data Sheets (MSDS) must be available for all dyes and solvents
- Almost all dye solution solvents are flammable and toxic by inhalation or skin absorption

Compressed Gas Hazards (common laser gases)

- Simple Asphyxiants - N_2, Ar, He, Kr
- Toxic gases
  - CO - chemical asphyxiant, depressed cardiac (25 ppm TLV)
  - CO_2 - asphyxiant, mild narcosis (5000 ppm TLV)
  - F - Corrosive to tissue, pulmonary edema (1 ppm TLV)
  - HCl - irritant to eyes, skin, mucous membrane(5 ppm Ceiling level)

Radiation Hazards

- Laser interacts with matter in material processing – plasma plume produced
  - Plasma is a source of optical radiation (UV, VIS)
- Collateral Radiation, generated from components necessary for laser operation
  - X-radiation from switches, other sources
  - Optical radiation from discharge tubes, plasma tubes, or optical pumping systems
  - Radio-frequency
  - X-ray and optical (UV, VIS, IR) - injurious to health

APPENDIX B: LASER CLASSIFICATION

Laser Classification Table	
Class1	Any laser or laser system containing a laser that cannot emit laser radiation at levels that are known to cause eye or skin injuring during normal operation. This does not apply to service periods requiring access to Class 1 enclosures containing higher-class lasers.
Class 1M	Considered incapable of producing hazardous exposure unless viewed with collecting optics.
Class 2	Visible lasers considered incapable of emitting laser radiation at levels that are known to cause skin or eye injury within the time period of the human eye aversion response (0.25 s).
Class 2M	Emits in the visible portion of the spectrum, and is potentially hazardous if viewed with collecting optics.
Class 3R	A laser system that is potentially hazardous under some direct and specular reflection viewing condition if the eye is appropriately focused and stable.
Class 3B	Medium-powered lasers (visible and invisible regions) that present a potential eye hazard for intrabeam (direct) or specular (mirror-like) conditions. Class 3B lasers do not present a diffuse (scatter) hazard or significant skin hazard except for higher powered 3B lasers operating at certain wavelength regions
Class 4	High-powered lasers (visible or invisible) considered to present potential acute hazard to the eye and skin for both intrabeam and diffused conditions. Also have potential hazard considerations for fire (ignition) and byproduct emissions from target or process materials.

Common Types of Lasers			
Laser	**Wavelenth (μm)**	**Type**	**Mode**
Argon (Ar)	0.488, 0.514, et.	gas	CW, P
Carbon Dioxide (CO2)	9.6, 10.6	gas	CW, P
Copper Vapor (Cu)	0.510, 0.578	gas	CW, P
Gallium Arsenide (GaAs)	0.820 - 0.95	semiconductor	CW, P
Helium Cadmium (HeCd)	0.325, 0.441	gas	CW
Helium Neon (HeNe)	0.543, 0.594, 0.612, 0.633, 1.152, 3.390	gas	CW
Mercury Vapor (Hg)	0.48, 0.615, 1.530, 1.813	gas	CW
Neodymium YAG (Nd:YAG)	0.266, 0.532, 1.064, 1.33	solid	CW, P
Nitrogen (N2)	0.869, 0.870, 0.889, 1.048, 1.231	gas	CW, P
Rhodamine 6G	0.570 - 0.650	liquid (dye)	CW, P
Ruby	0.694	solid	P
Ti :Sapphire	0.670	solid	CW, P
Water Vapor (H2O)	27.974, 33.033	gas	CW
Xenon Chloride	0.308	gas	CW, P

CW = continuous wave laser (continuous output for a period of ≥ 0.25 seconds).

P = pulsed laser (laser which delivers its energy in the form of a single pulse, or a train of pulses, with the pulse duration < 0.25 seconds).

APPENDIX C: CONTROL MEASURES FOR LASERS

Administrative Control	Class 1/1M	Class 2/2M	Class 3R	Class 3B	Class 4
Standard Operating Procedures 4.4.1				Recmd	**Req**
Education and Training 4.4.3		Recmd	Recmd	**Req**	**Req**
Authorized Personnel 4.4.4				**Req**	**Req**
Alignment Procedures 4.4.5	**Req if enclosed 3B/4**	**Req if enclosed 3B/4**	**Req if enclosed 3B/4**	**Req**	**Req**
Protective Equipment 4.6				**Req**	**Req**
Spectator Control 4.4.6				**Req**	**Req**
Specified Service Personnel 4.4.7	**Req if enclosed 3B/4**	**Req if enclosed 3B/4**	**Req if enclosed 3B/4**	**Req**	**Req**
Protective Eyewear 4.6.2				**Req**	**Req**
Window Protection 4.6.3				**Req**	**Req**
Protective Barriers and Curtains 4.6.4				Recmd	Recmd
Skin Protection 4.6.6				**Req** for UV excimers	**Req** for UV excimers
Warning Signs and Labels 4.7		Recmd	Recmd	**Req**	**Req**
Eye Examination 6.2				Recmd	Recmd

Req – REQUIRED Recmd – RECOMMENDED

Engineering Control	Class 1/1M	Class 2/2M	Class 3R	Class 3B	Class 4
Protective Housing 4.3.1	**Req**	**Req**	**Req**	**Req**	**Req**
Interlock; Removable Prot. Housing 4.3.2	**Req** if enclosed 3B/4	**Req** if enclosed 3B/4	**Req** if enclosed 3B/4	**Req**	**Req**
Service Access Panel 4.3.3	**Req** if enclosed 3B/4	**Req** if enclosed 3B/4	**Req** if enclosed 3B/4	**Req**	**Req**
Key Control 4.3.4				Recmd	**Req**
Fully Open Beam Path 4.3.6.1				**Req**	**Req**
Limited Open Beam Path 4.3.6.1				**Req**	**Req**
Remote Interlock Connector 4.3.7				Recmd	**Req**
Beam Stop or Attenuator 4.3.8				Recmd	**Req**
Activation Warning Systems 4.3.9.4				Recmd	
Indoor Laser Controlled Area 4.3.10	Recmd M	Recmd M		**Req**	**Req**
Temporary Laser Controlled Area 4.3.12	**Req** if enclosed 3B/4	**Req** if enclosed 3B/4	**Req** if enclosed 3B/4	**Req**	**Req**
Controlled Operation 4.3.13					Recmd
Equipment Labels 4.3.14 & 4.7	**Req**	**Req**	**Req**	**Req**	**Req**
Area Warning Sign and Activatn. Warning 4.3.9		**Req**	**Req**	**Req**	**Req**

Req – REQUIRED Recmd – RECOMMENDED

** When using **Excimer lasers in the UV regions** (typically laser welding or cutting applications), skin protection is best achieved through engineering controls. A subordinate, additional line of protection is the use of PPE (skin covers, sun screen cream, gloves, or lab coats).

APPENDIX D: FORMS

LASER EYE EXAMINATION FORM AND PROCEDURE

The UCLA Laser Safety Policy requires that all users of Class 3B and Class 4 lasers have eye examinations following any suspect laser injury and recommends that all users of Class 3B and Class 4 lasers have eye examinations prior to their participation in laser work and prior to their termination of their use of lasers. The medical eye examinations are useful in determining if individuals are pre-disposed to chronic laser injuries and serve as a baseline against which accidental eye damage can be measured. In the event of an accidental exposure, eye examinations may be used to assist with early detection of biological damage.

To receive an eye exam, please follow the instructions below:

1. Call the University Ophthalmology Associates (UOA) at extension 53090 to schedule an appointment for the eye examination. Inform them of which department you are from.
2. Complete the Laser User Eye Examination Form. A copy of this form can be found on this page of the manual.
3. Bring the completed Authorization Form with you to your scheduled exam. You will be required to give them the form at the exam. Your exam will be on the first floor of the Jules Stein Eye Research Center. Jules Stein is located on the south side of campus adjacent to the UCLA Medical Center.
4. Your exam will take approximately 2 hours. Since your eyes will be dilated during the exam, you should not plan to drive a car for 4 to 6 hours after the exam. Sunglasses may be useful to control glare.
5. The results of your exam will be forwarded to the UCLA Occupational Health Facility (OHF), where the results will be reviewed and a permanent record kept. OHF will inform the Laser Safety Officer if an individual is not cleared for continuing work.

<u>Laser User Eye Examination Authorization Form</u>

The person named below is authorized to undergo the laser eye examination recommended for Class 3B and Class 4 laser operators. The exam will be conducted by University Ophthalmology Associates (UOA), located in the Jules Stein Eye Research Center, 310-825-3090.

Date: _______________

Department name: ____

Department accounting representative: ______________________________________
Department accounting representative extension: ____________________________

University account number (thirteen digit account number for your lab):
____

User's name and extension: ____

Student or employee ID number: ____

LASER SAFETY SELF-INSPECTION CHECKLIST

PI/Lab Supervisor: ______________________ Inspected By: ______________________ Date: __________

Building & Room: ____

Contact (email and phone): ____

	Y	N	NA	Comments
1. Are lasers classified appropriately (2, 2M, 3R, 3B, 4)?				
2. Are written SOP's are in place?				
3. Are written alignment procedures are available?				
4. Are written maintenance procedures are available?				
5. Have all laser users attended appropriate training?				
6. Are all lasers labeled correctly?				
7. Have appropriate warning signs been posted at eye level at all entrances to the laser lab?				
8. If necessary, are illuminated warning signs in place?				
9. Is protective housings present and in good condition?				
10. Are there beam enclosures?				
11. Do surfaces minimize specular reflections?				
12. Is there any exposed wiring or circuits?				
13. Are windows and ports, which could allow a laser beam to stray into uncontrolled areas, covered or protected with non-reflective material during laser operation?				

14. Are beam stops present at the end of all beam paths? Are they non-combustible?				
15. Are barriers and screens non-combustible? Are there any burn holes?				
16. Is appropriate PPE available? Is it being used?				
17. Do laser users wear jewelry or watches while laser is operating?				
Class 3B and 4 Lasers				
18. Have all commercially produced Class 3B and Class 4 lasers, and all lasers made or modified on campus, been registered with the LSO?				
19. Do protective housing contain interlocks?				
20. Is spectator access limited?				
21. Has the nominal hazard zone been determined?				
Class 4 Lasers				
22. Does the entry to the controlled area have failsafe interlocks?				
23. Are only authorized personnel permitted in laser lab?				
24. Does the laser have remote fire capability?				
Is an inspective covering the items listed below performed prior to each laser operation?				
25. Is protective eyewear appropriate for laser operation?				
26. Is protective eyewear clean and free of damage?				
27. Are all beams traced and dumped?				
28. Are beam paths enclosed where possible?				

29. Is the optical bench free of unnecessary reflective items?				
30. If a beam crosses a walkway, are there posted barriers? Is a rope or chain placed across the path during laser operation?				
31. **Were any safety deficiencies found?**				
32. **Please list and describe the corrective actions that were taken for any identified safety deficiencies.**				

UCLA LASER INSPECTION FORM

UNIVERSITY OF CALIFORNIA, LOS ANGELES ____

Office of Environment, Health, & Safety

LASER INSPECTION FORM
Class 3B and Class 4 Lasers and Laser Systems

Inspector: ______________ Date of Inspection: _________Location (Building/Room): ________________ Department:________________

Name of Principal Investigator: ___________________ Phone # _________ Name of Lab Contact:______________ Phone # ___________

Laser Type: _______________ Class: ___________ Model # ___________ Serial # _________________ Production Class: ____________

Other Information: ____

LASER POSTING, LABELING AND ROOM SECURITY MEASURES:

Entrances properly posted: Y N Comments: ____

Room security adequate: Y N Comments: ____

Windows/doorways/open portals in room covered: Y N Comments: ____

Entry way interlock system: Y N Comments: ____

Interlock functioning: Y N Comments: ____

A door, blocking barrier, curtain, etc. at entryway: Y N NR Comments: ____

Laser status indicator outside room: Y N Comments: ____

Laser class label in place: Y N Comments: ____

Laser hazard label in place: Y N Comments: ____

LASER UNIT SAFETY CONTROL MEASURES:

Protective housing in place: Y N Comments: ____

____

Interlock on housing: Y N Comments: ____

Interlock on housing function: Y N Comments: ____

Beam shutter present: Y N Comments: ____

Key control: Y N Comments: ____

Laser activation warning system (with emission delay) in place: Y N Comments: __________________________________

Remote interlock connector (emergency shutoff) available: Y N Comments: ______________________________________

ENGINEERING SAFETY CONTROL MEASURES:

Laser secured to table: Y N Comments: ____

Laser optics secured to prevent stray beams: Y N Comments: ____

Exposed beam path at normal eye level: Y N Comments: ____

Enclosed beam path: Y N Comments: ____

Limited open beam path: Y N Comments: ____

Totally open beam path: Y N Comments: ____

Beam barriers in place: Y N Comments: ____

Beam stops in place: Y N Comments: ____

Beam intensity reduced through filtration: Y N Comments: ____

Remote viewing of beam: Y N Comments: ____

Reflective materials kept out of beam path: Y N Comments: ____

Laser user checking for stray beams: Y N Comments: ____

Physical evidence of stray beams: Y N Comments: ____

ADMINISTRATIVE AND PROCEDURAL SAFETY CONTROL MEASURES:

Standard Operating Procedures (SOPS) are available: Y N Comments: ____________________

Alignment procedures are available: Y N Comments: ____________________

Laser operate by authorized personnel: Y N Comments: ____________________

Excessive power/radiant energy accessible for required application: Y N Comments: ____________________

Appropriate action take for spectator control: Y N Comments: ____________________

All supervisors/workers have met the laser safety training requirement as per section 6 of the Laser Safety Program: Y N

Comments: ____________________

Has homebuilt/modified laser/laser system been classified: Y N Comments: ____________________

Proper laser eye protection available: Y N Comments: ____________________

Proper skin protection available: Y N Comments: ____________________

OTHER SAFETY MEASURES

All Class 3B/4 lasers and laser systems under the jurisdiction of this PI have been registered per section 4 of the laser safety program: Y N

Comments: ____________________

All supervisors/workers have met the laser safety medical surveillance requirement as per section 8 of the laser safety program: Y N

Comments: ____________________

Accident forms are available and accidents are reported as per section 7 of the laser safety program: Y N Comments: ____________

NON BEAM HAZARDS:

Toxic laser media in use: Y N Comments: ____________________

Hazardous laser media stored properly: Y N Comments:____________________

Cryogens in use: Y N Comments: ____________________

Compressed gas in use: Y N Comments: ____________________

Gas cylinders properly restrained: Y N Comments: ____________________

Fume hood for dye mixing: Y N Comments:____________________

Laser Generated Air Contaminant (LGAC) production: Y N Comments: ____________________

High voltage power hazard: Y N Comments: ____________________

Other electrical hazards: Y N Comments: ____________________

Collateral and plasma radiation hazard: Y N Comments: ____________________

Fire hazard: Y N Comments: ____________________

Explosion hazard: Y N Comments: ____________________

Mechanical hazards: Y N Comments: ____________________

Noise/Vibration hazards: Y N Comments: ____________________

Proper disposal of chemical wastes: Y N Comments: ____________________

ADDITIONAL COMMENTS:

____
____
____
____
____

SUMMARY OF ACTION REQUIRED

- Acceptable Safety Practices
- Improved Safety Measure(s) Required --- **minor issue(s)** to be addressed
- Improved Safety Measure(s) Required --- **major issue(s)** to be addressed
- Unacceptable Safety Practice(s) --- Requires action by following date(s): ____________________

Legend: **Y** – Yes, **N** – No, **NA** – Not Applicable, **NR** – Not Required MAY 2008

LASER PURCHASE REQUISITION DETAILS

LSO ID# ____________________		**Reviewed By** _____________________

PR Number _______________		**Approved By** ____________	**Date** _______

Dates	**Review**	**Approval**	**Purchase**	**Receipt**

How Acquired	Purchased Donated Assembled Other:

Contact Information	**Name**	**Phone**	**Email**
PI			
Lab Manager			
Primary Operator			
Other Contact			

Proposed Loc'n	**Bldg**	**Room**	**Dept**

Laser Information (in use)			
Class			
Type			
Manufacturer		Model	
Max Power			
Wavelength			
Emission Type	CW Pulsed	Pulse Duration	
Fiber Optics	Yes No		
Beam Exposed	Yes No		
Fixed	Yes No		
Alignment By	UCLA Vendor		
More Lasers in Lab	Yes No		

Purpose of Equipment

Other Information

APPENDIX E: INSPECTION CRITERIA AND PERFORMANCE EXPECTATIONS

This chapter describes laser safety performance expectations for the maintenance of a safe working environment and helps laser labs prepare for inspections and periodic audits. To provide consistency during the inspection process, EH&S and the Laser Safety Committee established criteria and a checklist for laser lab inspections.

The following items are inspected by the LSO during laser lab site visits:

1. **Self-Inspection Checklists**
   All laser labs must perform an initial self-inspection using the *Laser Lab Self-Inspection Checklist* (see Appendix F) and annually thereafter. Copies of the self-inspection must be forwarded to the LSO and kept on file in the Laser Safety Manual or other designated location.

2. **Labels and Signs**
   It is imperative that warning placards are posted, illuminated warning signs are installed and functioning, and all lasers are properly labeled.

   Warning signs must list the laser class, special precautionary instructions, wavelength, pulse duration, and maximum output. Labels must conspicuously delineate the laser type and class. Refer to Chapter 8 (Page 24 and 25) for more detailed label and signage requirements.

3. **Beam Enclosures and Containment**
   The purpose of a beam enclosure is to contain the laser beam and any stray radiation that may emanate from it. Beam blocks must be made of non-combustible material that can withstand the power output expected to strike the block. The beam block must not transmit the wavelength and must not be reflective. The LSO will verify that beam enclosures and beam blocks are appropriate to the laser.

4. **Eye Protection and other Personal Protective Equipment (PPE)**
   PPE must be labeled, organized, and readily available to all researchers and visitors in laser labs. Researchers must also be properly trained to know what PPE is required and advisable for specific lasers.

5. **Interlock Systems**
   Safety checks on interlock systems will be conducted by the LSO.
   The LSO will verify that quarterly interlock checks have been performed by examining the interlock log kept on file in the Laser Safety Manual or other designated location.
   The LSO will also verify that alignment procedure guidelines are in place.

6. **Electrical and Fire Hazards**
   The LSO will inspect the condition of electrical equipment and supply mechanisms for labeling and conditions that may cause release of electrical power to personnel.
   Electrical safety checks will include cabling, switching, grounding mechanisms and circuitry that is open to equipment operators and can cause a potential electrical threat.
   Storage of solvents and gases will be inspected to ensure that they do not constitute a primary fire hazard and are protected from interaction with potential electrical hazards.
   As applicable, the LSO will inspect for fire abatement equipment to ensure it is certified, currently inspected and available for all users.

7. **Safety, SOP and other Documentation**
   Standard Operating Procedures for the safe operation of all laser equipment and Safety Procedures that adequately address response to emergency situations in compliance with UCLA policies and Laser Safety Program requirements will be inspected and reviewed. Such documentation will include electrical lock-out/tag-out procedures.
   The LSO will verify the accessibility and availability of this documentation to all users.
   Training records for all employees will be inspected and reviewed.

8. **Housekeeping**
   In any lab good housekeeping is essential to maintaining a safe and productive working environment.

   It is the responsibility of laser users to;
   - Maintain debris-free laser work surfaces that are clear of all non-essential reflective materials.
   - Organize storage areas so that they are orderly and free of clutter.
   - Remove and store unused equipment and supplies
   - Proactively identify tripping and slipping hazards
   - Ensure that emergency lighting is in place and functional

   The LSO is available to assist in lab design and reconfiguration.

See *Appendix D: UCLA Laboratory Safety Self-Inspection Checklist* for more information.

APPENDIX F: INJURY PREVENTION AND CONTROLS

Certain administrative, procedural, and engineered safety control measures must be adhered to when setting up and using a laser laboratory. The LSO may authorize alternate administrative, procedural, or engineered controls to obtain equivalent laser safety protection when certain engineered controls are not feasible or are inappropriate. This substitution will be based on a laser hazard evaluation to be completed by the LSO. The information below refers to Class 3B and Class 4 lasers, except where indicated.

8.1 ENGINEERED CONTROLS

Door Interlock Mechanisms

The ANSI Z136.1 guidelines specify that access doors to a controlled laser area in which a Class 3B or Class 4 laser is being operated must be provided with entryway interlocks. The following plans for door interlock systems must include:

- A key switch with an override signal to enter the laser room without disabling the laser power.
- A manual override switch for entry permission from inside the laboratory.
- A safety interlock to control the shutter or beam stop when the room is entered without use of an override key or switch. The interlocked switch either shuts down or attenuates the beam.
- A requirement for the signal to be restarted manually after an action by the interlock switch.

EH&S should be contacted when installing door interlock systems to ensure that the system is set up appropriately.

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

Accessibility Restrictions

Access to laboratories which are solely used for lasers or laser systems must be controlled. Only personnel who are authorized by the Principle Investigator or lab manager are allowed access to such labs.

All other laboratories which use lasers or laser systems must initiate special precautions to prevent unauthorized access to the lasers. Such precautions may include:

- A separate controlled-access area within the lab
- Key controls
- Laser curtains

Example of a controlled entry device for a laser lab. The device reads, "Laser Beam on – controlled entry". Setting modes: Safe, Laser on, System shot, and Combination Key at the entrance.

Protective Housings (all classes)

A protective housing shall be provided for all classes of lasers or laser systems where practical. Protective housings which enclose Class 3B or Class 4 lasers must be provided with an interlock system which is activated when the protective housing is opened during operation and maintenance.

Key and Coded Access Control

A Class 4 laser or laser system should be provided with a master switch. This master switch shall effect beam and/or system activation and shutoff and shall be operated by a key or by coded access.

When unattended, lasers must be de-energized and secured from unauthorized use. If the laser system requires a key for activation, the key must be removed from the console and secured. Similarly, if coded access is required, the code must be entered and the laser deactivated. If it is necessary to operate a laser while unattended, the room must be locked. During periods of prolonged non-use (e.g. laser storage), the master switch should be left in a disabled condition (key removed or equivalent).

Beam Paths

Laser beam paths and any potentially hazardous reflections should be enclosed, if possible. If the enclosure material is not obviously opaque material, the Principal Investigator must document the optical density of the material for the wavelength(s) of the laser used. When the entire beam is enclosed and the enclosure fulfills all requirements of a protective housing, the requirements of Class 1 are fulfilled and no further controls are required for normal operations (not including alignment, system service and troubleshooting). For a limited open beam path, or a totally unenclosed beam path, a hazard analysis must be done to establish the nominal hazard zone (the space within which the level of direct, reflected, or scattered radiation during operation exceeds the applicable MPE). The hazard analysis can be undertaken by the Laser

Safety Officer and the Principle Investigator. Please consult Appendix A to determine the laser safety officers for your area.
All Class 3B and Class 4 lasers or laser systems must be provided with a permanently attached beam stop or attenuator. The beam stop or attenuator must be capable of preventing access to laser radiation in excess of the MPE level.

If enclosing the beam is not practical, other beam control measures must be used, including:

- Confining the beam path to the optical bench if possible. Do not traverse populated areas or trafficked areas. If traversing trafficked areas is necessary, access to the area should be restricted through the use of chains, ropes or other barriers.
- Covering all windows leaving the Laser Controlled Area with non-reflective or diffuse reflective material.
- Installing fire retardant material for use as a barrier for Class 4 lasers.
- Turning the laser off or utilize beam shutters or caps when laser transmission is not required.
- Terminating the beam at the end of its useful path. Beam stops should be secured with strong mechanical mounts to avoid the possibility of beam blocks dropping and exposing individuals to high intensity beams.
- Locating the beam path such that it is not at eye level for person standing or sitting.
- Orienting the beam so that it is not directed toward any doors.
- Orienting the beam so that it is not directed upward at any time during alignment or operation.
- Creating an entryway barrier using appropriate curtains, screens, etc. to block or sufficiently attenuate a beam to below the MPE at the entry
- Substitution of a lower powered laser or the use of reduced power for certain processes

Lighting: Adequate lighting is necessary in controlled areas.
- If lights are extinguished during laser operation, provide control switches in convenient locations or install radio controlled switching.
- Luminescent strips must be used to identify table and equipment corners, switch locations, aisles, etc.
- Install emergency lighting when ambient light is not sufficient for safe egress from a laser area during an electrical power failure.
- Entrances to Class 4 Laser Controlled Areas must be equipped with a readily visible indication that the laser is in operation (e.g. an indicator light). Alternate methods, as approved by the LSO may be used to signal laser use. The light must be turned on, either manually or automatically, when the laser is in operation.

Ventilation

Gas cabinets must be used to provide a ventilating enclosure in labs using fluorine or hydrogen fluoride as an excitation medium in an excimer type laser system. If fluorine gas is used for any purposes, it must be contained in a functional fume hood or an equivalent ventilated enclosed space if a gas cabinet is not available. All gas cabinets must:

- Operate under negative pressure in relation to the surrounding area.
- Be provided with self closing, limited access ports or non-combustible windows to give access to controls.
- Operate with an average velocity of ventilation at the access ports or windows of 200 feet per minute.
- Connect to an exhaust system.
- Be provided with self-closing doors.
- Be constructed of at least 18-gauge steel.

Protection from Electrical Hazards

The use of lasers can present an electric shock hazard. Shocks may occur from contact with exposed energized parts, device control, and power supply conductors operating at potentials of 50 volts and above. These exposures can occur during laser set up, installation, maintenance, or servicing when equipment protective covers are removed.

The following precautions must be taken to prevent electrical hazards:

- Barrier system: Protection against accidental contact with energized conductors must be provided by means of a barrier system. This is the primary method to prevent electric shock accidents with laser equipment.
- Shield: Capacitors must be tested to ensure they could withstand the highest electric potential. Shielding must be in place to prevent injury from a possible capacitor explosion.
- Ground: All laser system components must be properly grounded.
- All electrical wiring must meet the requirements of the National Electric Code. Facilities Electricians may be consulted.
- The electrical circuits should be evaluated for the possibility of electrical fires.
- Label: Laser systems must be marked with operating voltage, frequency, and power or current.
- Secure electrical cords and minimize wires and cables on the floor to prevent a tripping hazard.
- Follow lock-out/ tag-out procedures when maintenance on lasers is required.
- Ensure wires and cords are properly insulated and not frayed. Electrical terminals must also be covered.
- Laser power supplies must be properly secured to prevent them from falling.
- When working on electrical components, use the buddy system.
- Do not work around standing water while the laser is in operation. Prepare for emergencies such as leaking cooling systems.

Protection from Flammability Hazards

Lasers are capable of igniting fuel sources, such as curtains and room furnishings, in a laboratory setting. Flammability hazards are increased with flammable gases are present.

The following precautions must be taken to decrease the risk of fire and explosion:

- Laser labs may require Fire Safety Certification. Contact the UCLA Fire Safety Department for further information about fire equipment, personnel training and certification.
- No dry or paper materials will be placed near the path of the beam.
- The laser will be placed in a stand-by mode whenever it is not directly aimed at the intended target.

Laser Dyes and Hazardous Chemicals

Many non-beam hazards may be present in a laser laboratory. Certain laser dyes are highly toxic and/or carcinogenic. All dyes should be treated as hazardous chemicals. All dyes should be reviewed to investigate the possibility for substitution with less toxic or volatile dyes or chemicals.

Since dyes need to be changed frequently, special care must be taken when handling them, including preparation of solutions as well as operation of the dye laser. Practically all solvents suitable for dye solutions are flammable and toxic by inhalation or skin absorption.

The following precautions should be taken when using laser dyes:

- Dye laser components should be leak-tested before using the actual dye solutions. All tubing connections should be securely fastened or clamped.
- Laser dye solutions should be prepared inside of a chemical fume hood.
- Personnel must use the appropriate personal protective equipment (PPE) when working with dyes to ensure eye and skin protection.
- Spill pans must be installed under pumps and reservoirs.
- Material Safety Data Sheets (MSDS) must be available for the dyes as well as any solvents.

Use of Optical Devices

Microscopes and other optical devices used to aid viewing may concentrate the amount of laser light which arrives at the eye. The resulting increase in light intensity level may be as much as the magnification of the optical device squared. It is critical to take precautions when using optical viewing devices to ensure that the instrument does not view the beam or a specular reflection directly. Microscopes used in laser work should be provided with an attenuation filter.

8.2 ADMINISTRATIVE CONTROLS

The LSO may apply alternate methods to achieve equivalent laser safety protection when some engineering controls are inappropriate. When necessary, these alternate methods may be administrative controls, including a written Standard Operating Procedure (SOP). Each SOP is reviewed by the Laser Safety Office prior to being adopted for use by the Approval Holder. Unless otherwise specified, these requirements apply to Class 3B and Class 4 lasers.

Labels

Lasers must be labeled to indicate the class and type of laser. A laser classification label must be conspicuously affixed to the laser housing. The laser users must keep labels current and legible. Lasers manufactured after August 1, 1976 must be classified and labeled by the manufacturer. It is the responsibility of the PI or lab supervisor to ensure that these labels are present.

Warning Signs

Class 2, 3 and 4 laser laboratories are required to have a **Laser Area Warning Sign** posted at each entrance to the laboratory at eye level.

These signs are specific to the lab and laser system; signs and sign holders are available from the Laser Safety Officer.

Class 2 and Class 3R laser system labs must display a YELLOW sign, specifying CAUTION, the location and that the room contains a Class 2 or Class 3R laser system.

Class 2 laser system signs should include text similar to;

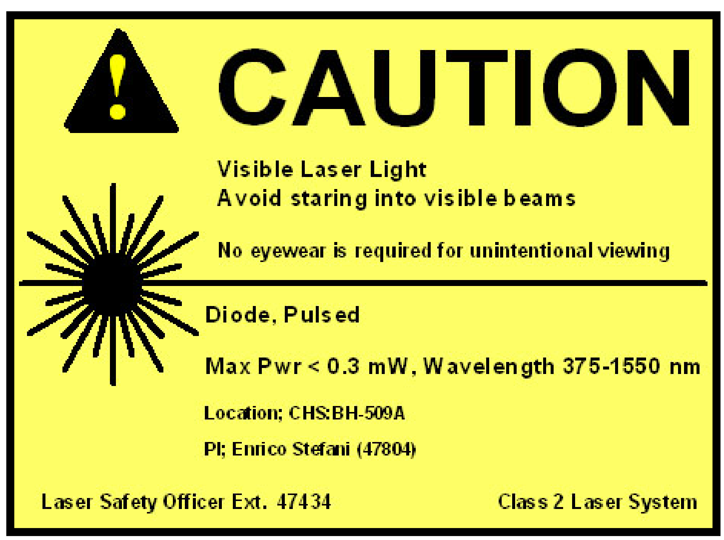
LASER RADIATION – DO NOT STARE INTO BEAM

Class 3R laser system signs should include text similar to;

LASER RADIATION – AVOID DIRECT EXPOSURE TO THE BEAM

All signs should also include type of laser, emitted wavelength, pulse duration, and maximum output of the laser system.

At right is an example of a Class 2 or Class 3R laser system Area Warning Sign.



Class 3B and Class 4 laser system labs must display a RED and WHITE sign, specifying DANGER, the location, laser specifics and that the room contains a Class 3B or Class 4 laser system. For labs with more than one laser or laser system, indicate the laser with the highest classification.

Class 3B laser system signs should include text similar to;

LASER RADIATION – DO NOT STARE INTO BEAM

Class 4 laser system signs should include text similar to;

LASER RADIATION – AVOID EYE OR SKIN EXPOSURE TO DIRECT OR SCATTERED RADIATION

All signs should also include type of laser, emitted wavelength, pulse duration, and maximum output of the laser system.

Below is an example of a Class 4 laser system Area Warning Sign.

Illuminated Warning Signs

ANSI guidelines call for the installation of illuminated warning signs. New laser laboratories must obtain them and existing laser labs must be retrofitted. These signs can be obtained from various suppliers (see Appendix C).

Some laser laboratories at UCLA have automatic illuminated signs above each entrance to a controlled laser area. The illuminated signs read “Laser in Operation, Do Not Enter”. These signs are connected to each laser in the room, so that if any laser is operating, the sign illuminates automatically. All of the laser laboratories in Young Hall East contain automatic illuminated signs. In other areas, illuminated signs must be operated manually.

Illuminated signs are to be used in conjunction with to the entrance warning signs for each laser lab.

Examples of illuminated warning signs

APPENDIX G: LASER ANATOMY

Lasers function by the introduction of energy into a laser optical cavity, which causes an excitation of electrons within the cavity, which results in the production of an emitted beam of laser light. An external light source "pumps" energy into the laser optical cavity, causing certain atoms to become excited. When these excited atoms return to their ground state, the electrons within the atoms release energy in the form of photons, which can be considered particles of light. The wavelength of the photons depends on the state of the electron's energy when the photon was released.

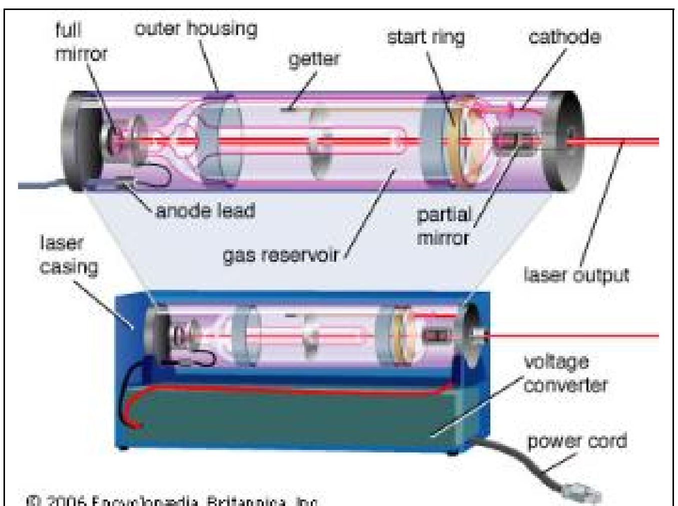
Laser light is different than normal light because it is;

- **Monochromatic** (i.e. it only has one wavelength)
- **Coherent** (i.e. it is organized)
- **Directional** (i.e. the light does not scatter).

Stimulated emission is necessary for a laser to emit a beam of light and this happens when photons encounter other atoms with electrons in the same excited state, which sets off a chain reaction.

There are mirrors at each end of the optical cavity. Photons are reflected off these mirrors and travel back and forth, stimulating the release of more photons of the same wavelength and phase. One of the mirrors is partially transparent, meaning that it reflects some light and lets some light through. The light that it lets through is the monochromatic, coherent, and directional release of a laser beam.

When a laser beam strikes matter, it can be absorbed, reflected, or transmitted. Opaque matter absorbs or reflects the beam, while transparent matter transmits the beam.



Elements of a Laser

APPENDIX H: LASER POINTER SAFETY

Most pen-sized laser pointers are battery powered and can cause eye damage if used improperly. The potential hazard is limited to looking directly into the laser beam with unprotected eyes. No hazard to the skin exists. Pen-sized laser pointers have become common presentation aids in recent years. These battery powered laser pointers produce a narrow bright red beam, are convenient to carry and use, are relatively inexpensive, and are readily available. Misuse of laser pointers, such as intentionally shining beams at individuals, is illegal.

The following guidelines for laser pointers must be followed:

- Laser pointers must be properly labeled with the appropriate laser hazard symbol. Pointers of > 0.5mW must also indicate the laser classification, maximum power output, and laser wavelength.
- The manufacturer's safety instructions provided with the laser must be reviewed before using a laser pointer.
- The owner of the laser pointer is responsible for its use at the University.
- Use of laser pointers should be limited to the intended purpose. Indiscriminate use may present an eye hazard.
- The laser beam must never be intentionally directed toward oneself or directed toward another person. A person must never intentionally stare into the laser beam.
- The laser pointer should be kept in a secure place and the beam should be turned off when not in use.
- Mirror like surfaces (such as glass, metal, and other highly reflective materials) should be avoided when directing the laser beam.
- Class 3R laser pointer use is prohibited when optically aided viewing of the beam is probable. Optical aids include telescopes, binoculars, viewing optics, and similar devices.
- Access to 3R laser pointers should be limited to responsible persons who have been informed of these guidelines by the owner or user

APPENDIX I: Laser Safety Officers

Colin Dimock, Radiation Safety Officer
Telephone: (310) 206-8204
E-mail: cdimock@ehs.ucla.edu

Mike Lawrence, Health Physicist
Telephone: (310) 794-7434
E-mail: lawrence@ehs.ucla.edu

APPENDIX J: PERSONAL PROTECTIVE EQUIPMENT (PPE)

Certain types of PPE are required when working with lasers. It is important to note that the eye is susceptible to serious damage from lasers. Both continuous wave and pulsed lasers are potentially dangerous to the eye. Pulsed lasers are often more hazardous because they generate powerful bursts of laser radiation that can damage the eyes in a number of very serious ways. Before any protective eyewear is used, it must be checked for defects and to verify it is suitable for the wavelengths of lasers in use.

The following requirements must be met:

- Protective eyewear must be worn whenever MPE levels may be exceeded; however, it is good practice to always wear eye protection when lasers are in use.
- Protective eyewear must be worn whenever Class 4 and 3B lasers are in use. Laser protective eyewear may include goggles, face shields, or prescription eye wear using special filter materials or reflective coatings to reduce the exposure to the eyes below the MPE.
- Protective eyewear must fit and be comfortable to wear.
- Protective eyewear must be approved by ANSI and clearly labeled with optical densities and wavelengths for which protection is afforded. Eye wear must be inspected periodically by the user for pitting and cracking of the attenuating material, and for mechanical integrity and light leaks in the frame.
- Laser eye protection in the form of goggles should be provided for each laser control area. The goggles should be kept in a protected and easily accessible location. They must be available for laser operators and visitors to laser areas. Each set of goggles must be clearly marked for the laser that they accompany. Any visitor to the laser area is required to use appropriate goggles.
- Eyewear provides protection over a narrow range of the laser spectrum. Eyewear designed for protection at one wavelength may afford little or no protection at another wavelength. Consult eyewear manufacturers and EH&S for proper selection of protective eyewear.
- Adequate skin protection must be provided to protect against acute exposure to high levels of laser radiation that may cause skin burns. This is especially true for chronic exposure to high levels of some UV wavelengths and may require face shields and garments that cover all bare skin.
- PPE is not a substitute for common sense and the use of good safety practices.

APPENDIX K: RESPONSIBILITIES

Laser Safety Committee

The Laser Safety Committee is comprised of the Chair, LSO, EH&S Director, various Principle Investigators and laser operators and is responsible for the following:

1. **Policies and Practices:** Provide guidance on appropriate controls and work procedures for laser systems. Review campus policies pertaining to the use of lasers. Provide guidance on training activities and provide laser safety training requirements.
2. **Approvals:** Approve operation of any laser acquired through purchase, transfer or assembly. Review requests for variances from the campus laser policies. Meet quarterly, or more frequently as needed, to review and update campus laser safety policies and approve acquisition applications for lasers of significant interest.

Laser Safety Officer (LSO)

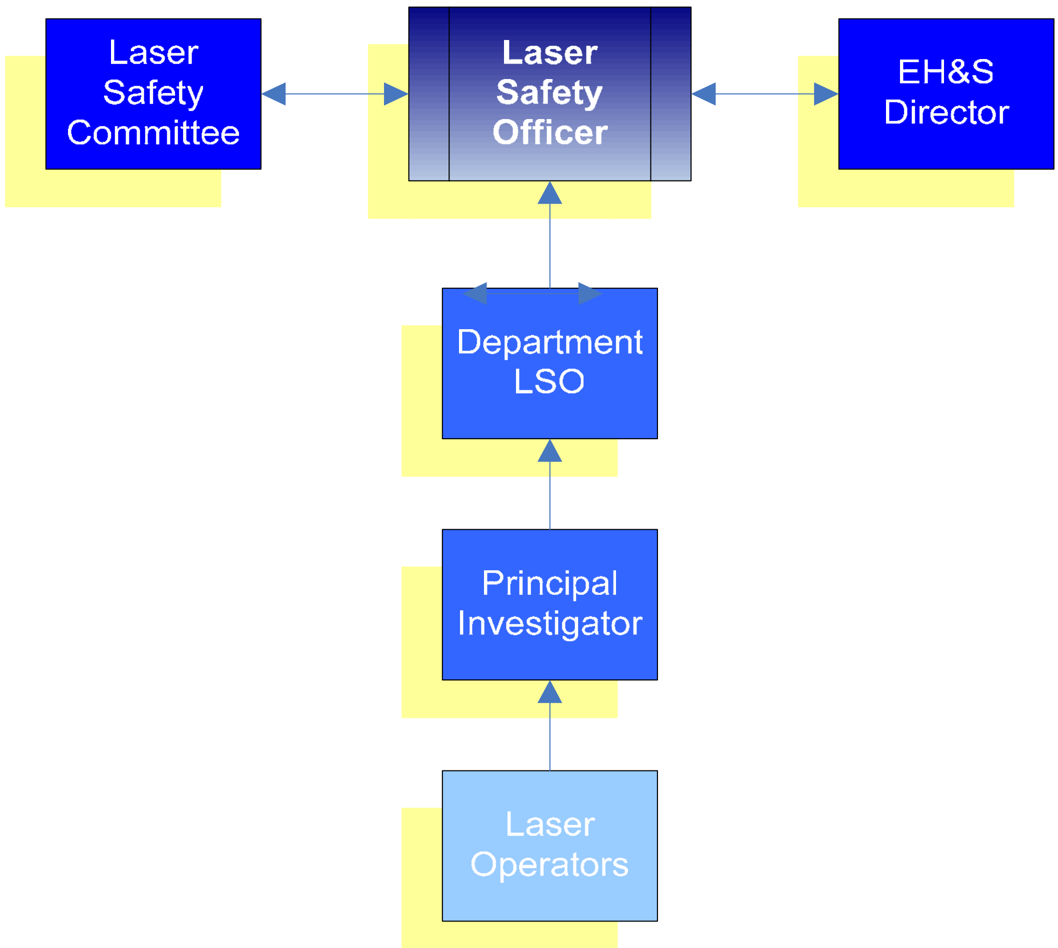
The LSO has been designated by the director of EH&S and has the authority and responsibility to monitor and enforce laser safety controls and effect the knowledgeable evaluation and control of laser hazards.

The LSO or his designee is responsible for the following:

1. **Safety Program:** Establish and maintain a UCLA Laser Safety Program that complies with all applicable requirements.
2. **Training:** Ensure the provision of laser safety training for personnel who are assigned to an area where lasers are operated, including initial and refresher laser safety training for all applicable laser users.
3. **Audits and Inspections:** Conduct regular lab inspections to ensure that safety requirements are in place and all compliance and control measures have been fulfilled. Conduct periodic surveillance of laser operations and submit reports of unsafe conditions or practices to supervisory personnel responsible for the laser operation with recommendations for corrective action.
4. **Accidents:** Oversee accident investigations involving lasers.
5. **Signs and Labels:** Provide and update laser safety area and door signs.
6. **Records and Inventory:** Maintain all records of lasers and laser operators.
7. **Laboratory and Equipment:** Review the design and quality of all personal protective equipment (PPE) and recommend standards for their use. Review designs for laser use areas.
8. **Policies and Procedures:** Assist campus organizations in the preparation of written procedures and precautions for laser operations. Periodically review and update the UCLA Laser Safety Manual.

LASER SAFETY COMMUNICATION STRUCTURE

UCLA Laser Safety Communication Structure



APPENDIX L: SCOPE OF PROGRAM

Pursuant to **UCLA Policy 811**, EH&S is responsible for the oversight, administration and enforcement of safety standards and work practices and has overall responsibility for laser operations on campus. The EH&S Radiation Safety Division oversees campus laser operations. The Radiation Safety Officer or designee will serve as the Laser Safety Officer (LSO) and is responsible for the implementation of safety standards and compliance with this manual. Trained and qualified individuals may be appointed as Department Laser Safety Officers (DLSO) to oversee laser safety operations within their particular department.

Oversight of laser usage at UCLA is achieved through a collaborative effort by the Laser Safety Committee (LSC), the LSO, Principle Investigators and Supervisors, and laser operators. The LSC is comprised of key Principal Investigators and EH&S Safety Personnel and is charged with reviewing laser registry forms and approving the acquisition of new Class 3B and Class 4 lasers. The LSC also makes policy recommendations to the University Administration.

The requirements and recommended procedures of this program are applicable to all individuals who use lasers and/or laser systems for research and education at UCLA.

This manual reflects the applicable laws and regulations regarding laser usage as outlined in Cal/OSHA regulations and in the ANSI (American National Standard for Safe Use of Lasers) handbook. This manual is a compilation of University Policies that must be adhered to in laser research and operations.
Cal/OSHA regulations can be obtained by visiting www.osha.gov.
Copies of the ANSI handbook can be purchased through the Laser Institute of America website, www.laserinstitute.org.

APPENDIX M: SETTING UP A LASER LAB

Setting up a laser laboratory is similar to setting up other kinds of laboratories with additional special considerations;

1. Notify the LSO of any decision to purchase, fabricate, alter, or otherwise acquire a Class 3R, 3B, or 4 laser or laser system by calling EH&S at 310-825-5689. Notify the LSO of any decision to transfer or relocate a Class 3R, 3B, or 4 laser or laser system.
2. The LSO will consult with the laser applicant by reviewing the hazards associated with the purchase or acquisition and making specific safety recommendations.
3. Submit Laser Registration Form to LSC. (See *Appendix H: UCLA Laser Registration Form*).
4. Upon approval of the Laser Registration Form, the laser applicant may proceed to set up the laser lab. The LSO is available for guidance and consultation on lab set-up.
5. See Chapter 8 on Injury Prevention for specific safety and lab set-up requirements.
6. General laser use is **not permitted** until the LSO has visited and approved the lab set-up and safety provisions prior to the onset of laser operations.

APPENDIX N: STANDARD OPERATING PROCEDURES

REQUIREMENTS AND RECOMMENDATIONS

Written Standard Operating Procedures or SOP's (ANSI Standard Z136.1-2007, 4.4.1);

- **Should be required and approved for Class 3B lasers** and laser systems
- **Shall be required and approved for Class 4 lasers** and laser systems
- The ANSI standard **requires that written SOP's are maintained with the laser equipment** for reference by the operator, maintenance and service personnel
- Shall address **beam and non-beam hazards**

ANSI standards do not require that all SOP's are contained in a single document. UCLA suggests that SOP's are logically organized and linked (e.g. Operating procedures and Emergency procedures may be in the same document) and all SOP's are stored together for accessibility and retrieval.

Standard Operating Procedures will include;

- **Operating Procedures** (see Operating Procedures, Laser Startup Procedure)
- **Maintenance Procedures** (see Maintenance, Trouble-Shooting and Service Procedures)
- **Service Procedures** (see Maintenance, Trouble-Shooting and Service Procedures)

UCLA requires that Standard Operating Procedures include details of or references to documents specifying;

- **Administrative Requirements for laser operation** (see Administrative Requirements)
- **Alignment Procedures or Requirements** (see Alignment Procedure)
- **Emergency Procedures**; may be incorporated in Operating Procedures (see Emergency Procedures)
- **Trouble-Shooting Procedures**; may be incorporated in Maintenance Procedures (see above)

The following topics should be addressed in the SOP's.

Equipment Description

In all procedures, a specific description is required that must include;

- The common name of the device, the location of the device
- The name/phone of the PI for the lab in which it is located
- The name/phone of the person who is primarily responsible for equipment operations.

The equipment description may involve details of laser system components that require individual alignment and start-up procedures and have separate power supplies.

Administrative Requirements

These will indicate the PI and Lab requirements for a worker to work as an authorized laser worker in the lab and will typically include;

- All laser workers must complete and pass Laser Safety Training at the UCLA Office of Environment Health and Safety. Refresher training must be completed every two years to maintain authorized worker status
- All laser workers must read and follow the UCLA Environment Health and Safety Laser Safety Manual.
- All workers who operate the XXX Laser must be trained in the safe operation of the laser and its components by the Lab Supervisor. The component manuals from Manufacturers are available for reference. After training, authorized laser workers will have their names entered in the laser training register. The lab supervisor will maintain and document the laser training reisters (worker name, scope, instructor and date).
- Only authorized laser workers (whose names are entered in the laser training register) are allowed to operate the XXX Laser and its components.
- All lab personnel must read and sign this document.

Additional Administrative Requirements may include;

- All lab personnel must have a laser eye exam
- No person is allowed to work in any of PI YYY's laboratories without adequate health insurance
- All lab personnel must review the Personal Protective Equipment for UCLA Research Laboratories Tutorial and be signed off on the Laboratory Hazard Assessment Tool Report
- Full body dosimetry monitoring is required for all personnel in this laser location

General Operating Requirements

A prefacing general statement relating to the overall lab laser environment may be included, such as;

Operating and aligning the XXX Laser is complex and involves several major components which are described in specific operating procedures. All workers and students are required to obtain a level of hands on proficiency with the laser system and must learn safe standard operating procedures. Becoming a proficient operator can take months or years. Therefore most of the laser operations will be initially performed by the lab supervisor with assistance from workers and students.

Interlocks

The location of interlocks should be specified and, if the interlock is particularly complex, an operating procedure may be required specifically for the operation of the interlock.

Basic Operational Requirements will include;

- Wear appropriate protective eyewear at all times in the laser area

- No one is allowed to operate the laser or components of the laser without training and permission from the lab supervisor
- No one is allowed to direct the laser at targets that are not approved by the lab supervisor and the PI
- No one is allowed to do maintenance on the laser or its components without permission from the lab supervisor.
- No one is allowed to alter the path of the laser for any purpose without permission and supervision of the lab supervisor
- No one is allowed to alter the components or normal set up of the laser for any purpose without permission and supervision of the lab supervisor
- No one is allowed to remove the laser safety covers without permission of the lab supervisor
- No one is allowed to interrupt the laser safety interlocks during normal operation of the laser. During service, maintenance and troubleshooting the lab supervisor and/or the laser manufacturer's representative may do repairs that require interruption of the safety interlocks. No other work is allowed in the laser area during those times
- Visitors are not allowed in the laser room while the laser or any component is emitting radiation
- All laser workers must follow the emergency procedures prescribed in Overview Operation and Alignment Procedures

Additional Basic Operational Requirements may include;

- No one is allowed to operate the laser or components of the laser while working alone
- No one is allowed to operate the laser or components of the laser on weekends or holidays without permission from the lab supervisor
- No desk chairs or any type of seating is allowed in the laser area
- No work projects other than laser work and relevant experimental work are allowed in the laser area

Following the basic requirements, include a section for worker, PI and Lab Supervisor acknowledgement that indicates the worker has read the document, has complied with all requirements and is approved as an authorized worker.

Worker name_____________________________________
Signature____ Date__________________

Principal Investigator name_________________________
Signature____ Date__________________

Lab Supervisor name______________________________
Signature____ Date__________________

Operating Procedures

Operating procedures will relate to the laser system, which may comprise several individual pieces of equipment. In this case it may be necessary to write a procedure for the startup and shutdown of each piece of equipment. The relative location and a short description of each component must be included so that there is no confusion regarding which component the SOP applies to.

The exact location of supporting documents (such as operator manuals, safety guides, calculation sheets, emergency procedures) must be specified as necessary in the procedure.

General Statement

Before the specific operating procedures, a general statement may be included that outlines the function of the laser system in broad terms, such as;
The XXX Laser produces high power short pulses at 800 nm wavelength. The laser works on the principle of chirped pulse amplification. Short pulses from the laser oscillator are first stretched in time to reduce the intensity, then amplified in a series of amplifiers and then recompressed to produce high power short pulses. The short, high power laser pulses are sent to the target where the experiments are performed.
In general XXX type lasers are pumped by green laser light at 532 nm and emit laser radiation at 800 nm. Without the green pump lasers the XXX laser will not emit radiation. Appropriate eyewear for these wavelengths is located in the case next to the entrance to the laser area.

Specific Equipment Description

A description of the characteristics and function of each system component may be included in the operating procedure, and some general examples follow;

Spitfire Pulse Stretcher and Regenerative Amplifier and Evolution Green Pump Laser.
Pulses from the oscillator are transported to the pulse stretcher and regenerative amplifier. Spitfire (manufactured by Spectra Physics) is the product name of the pulse stretcher and regenerative amplifier combination. The Spitfire runs at 1 kHz, produces about 1 watt average power and is a Class 4 laser. The Spitfire is pumped by an Evolution green pump laser also manufacture by Spectra Physics. The Evolution runs at 1 kHz, produces about 10 watts of average power and is considered a Class 4 laser. As part of their training, workers and students are required to read the Evolution users manual. Chapter 2 involves Safety; Chapter 5 involves Operation and includes System Start-up and Shut down procedures.

As part of their training, workers and students are required to read the Spitfire users manual, Chapters 1-5. The Spitfire safety information is integrated into the operation text of the manual. Chapters 1 contains the start up and Chapter 2 is shut down *procedure. Workers and students will be trained how to operate the Evolution in conjunction with the Spitfire by the lab supervisor.*

The Spitfire produces enough 800nm laser light to view the beam with an IR viewer. Alignment apertures are set up on the beam path from the Spitfire through the amplifiers, compressor, focusing optic, and to the target. Workers and students will be trained to use an IR viewer and the camera alignment system to check the alignment and adjust the beam path through the apertures as needed.

Beam dumping and sampling
Typically the laser is sent to a beam dump inside the vacuum chamber. In some cases less than 1% of the laser light is taken out of the vacuum chamber and sampled for optical measurements using cameras, spectrographs, auto-correlators etc. Because of the high powers associated with this laser, all care should be taken even when working with sampled beams. Students and workers will be trained to use sampled beams and measurement devices safely.

Where **alignment procedures** are indicated, these must be written as separate documents or referenced from the manufacturer operating manual.

Laser Startup Procedure

If specific equipment descriptions are not included, ensure that they are provided as part of each individual startup procedure, which should describe the step-by-step startup process. A typical startup procedure could include;

- Obtain the interlock key from your instructor
- Obtain and wear appropriate laser safety eyewear
- Ensure that emergency telephone numbers are readily available.
- Ensure everyone in the lab removes and stores wristwatches, reflective jewelry and conceals plastic ID cards
- Let everyone know you are going to start the laser by audible means
- Clear the laser lab as necessary. Ensure that all unauthorized people leave the room.
- Secure the laboratory door and then activate the laboratory interlock system. (describe the interlock process) Be prepared to turn the laser off immediately if any unauthorized person or a person without laser safety eyewear enters the laboratory.
- Activate the Laser Area operating light
- Place the Area Laser sign in the ‘Laser In Use’ position
- Begin with laser shutter closed and beam path to compressor blocked
- Remove all plastic bags from beam line optics
- Open valves to the building recirculating water
- Turn on laser water chillers
- Turn on timing units and diagnostic scopes
- Turn on vacuum pump
- Turn on power supplies to green pump lasers and allow ~2 hour warm up
- Mode lock oscillator

- Tune oscillator spectra to reference trace
- Turn on Evolution
- Tune Spitfire spectra to reference trace
- Check you are switching out correct pulse
- Check alignment through MP1 and MP2. Adjust if needed
- Check alignment through grating compressor and vacuum chamber
- Pump down vacuum chamber
- Always use the lowest beam power necessary to perform the procedure. Increase beam power if necessary and complete the assigned task.

Startup will obviously vary between devices and equipment, but the process should be comprehensive, specific, sequentially accurate and include all steps to ensure personnel, equipment and laboratory safety.

A procedure for **shutting down the system** is also useful and may be required if there are significant issues for the protection of laboratory resources.

Emergency Procedures

Operating Procedures should include Emergency Procedures or references to them. A typical Emergency Procedure will include;

- Alert others to the emergency situation
- Shut down laser immediately. Turn the keys to the green pump lasers (XXX, YYY, ZZZ) to the off position
- If necessary in the event of an emergency situation such as injury or fire, dial 911 from a campus phone
- If there is a fire, get everyone out of the laboratory immediately. At the same time shout “FIRE” loudly and frequently. Turn on a fire alarm. Fire extinguishers are located next to laser area entrance. Do not try to “fight” the fire from inside the laboratory. Do it from the doorway so that you have an escape route.
- Contact the PI or the Lab Supervisor as soon as possible
- All laser incidents that are outside the scope of routine operations must be reported to the EH&S Hotline (x59797)

Maintenance, Trouble-Shooting and Service Procedures

These represent a departure from normal operating circumstances and must describe the circumstances and exceptional safety measures including;

- Temporary safety signage
- Special operating constraints (e.g. removal of all personnel except service person and lab supervisor)
- References to service personnel requirements (evidence of training and qualifications are required)
- Other specific operational procedures required for the inherent safety of personnel equipment and the lab environment

Alignment Procedures
Because of the incidence of eye hazards during beam alignment, laser alignment must be performed to ensure that the primary beam, or a specular or diffuse reflection of the beam, does not expose the eye to a level above the applicable MPE.

The group that normally uses the laser should write the alignment procedures. If alignment is performed by a qualified vendor, the vendor should be defined in the SOP. The frequency of alignment should also be noted in the SOP.

Alignment procedures need to adequately describe the alignment process, which may be very complex. In the event that the process changes significantly on a regular basis, a general **alignment requirement** must be written that accommodates the safety requirements that will prevail under any lab conditions, such as;

The following steps must be adhered to during laser alignment:

- **ONLY LASER USERS AUTHORIZED BY THIS LAB SHALL OPERATE AND ALIGN THIS LASER**
- Obtain the interlock key from your Lab Supervisor and/or ensure that your lab supervisor knows you will be working with the laser
- Ensure that emergency telephone numbers are readily available
- Ensure that appropriate laser safety eyewear is worn by everyone in the laboratory.
- Ensure that all unauthorized people leave the room
- Secure the laboratory door and activate the laboratory interlock system. Be prepared to turn the laser off immediately if any unauthorized person or a person without laser safety eyewear enters the laboratory
- Ensure everyone in the lab removes and stores wristwatches, reflective jewelry and conceals plastic ID cards
- Set up the necessary optical components for the experiment
- Check that all beam stops are in place and that unrequired and unnecessary reflective surfaces are removed from the optical path. One beam block should be placed behind the first optical component. A second beam block should be placed behind the second optical component
- Turn on the cooling water to the laser
- Set the laser power control to the lowest power value possible
- Insert the interlock key into the laser switch and unlock the laser
- Announce loudly, with a short countdown that you are turning the laser on
- Turn on the laser
- Align the optical components starting with the component nearest the laser. When that component is aligned, move the first beam block behind the third optical component and align the second optical component. Repeat this procedure until the entire optical system is aligned. It is important that laser beam alignment is limited to one new component at a time until the entire system is aligned. This will minimize uncontrolled reflection during the alignment process
- When alignment to the target is completed, carefully check the beam path for accurate tracking. Modify the alignment to remove all stray and unwanted beams as necessary.

- When you are certain that the beam path is correct and that there are stray beams, increase power to the necessary levels for required operation

If you will not be proceeding with a laser experiment;

- Power down the laser and switch off all equipment. Allow the laser to cool down and turn off the cooling water
- Remove the key from the laser interlock switch.
- Ensure that lab equipment and the lab itself is secure before leaving the lab
- Return the interlock key to the Lab Supervisor
- Return laser safety eyewear to the correct storage location.

NOTE

- Do not remove safety eyewear at any time during the alignment process. If you cannot see a faint image of the beam, your eyewear is of the wrong optical density.
- Turn off the laser and obtain eyewear with the correct optical density

Other items that may be included in SOP's

Medical Surveillance and Eye Examination Requirements

Individuals operating Class 1, 2, and 3R lasers are exempt from eye exams.

Laser operators or individuals who will work in areas where there may be exposure to laser radiation from a Class 3B or Class 4 laser should have pre-assignment and termination eye examinations.

Medical examination must be performed as soon as possible (within 48 hours) when a suspected injury or adverse effect form laser exposure occurs. Report all laser injuries to EH&S Injuries Report Hotline (x59797) immediately. An eye examination is also recommended when the employee terminates from the laboratory. Authorization Forms for Laser Users Eye Examinations can be obtained from the Laser Safety Officer (see Appendix A).

Laser personnel must report any symptoms which may indicate potential eye exposure to a laser beam to their supervisors. Such symptoms may include a persistent after-image of a light source, a scratchy or burning feeling, pain, reddening, etc. Supervisors must report the exposures to EH&S or to the Laser Safety Officer.

Laser-produced eye injuries are <u>preventable</u>. Common causes of laser injury are:

- Unanticipated eye exposure during alignment
- Fatigue, leading to carelessness or inappropriate shortcuts.
- Misaligned optics and upwardly-directed beams.
- Eye protection not worn or the wrong eyewear worn.
- Overconfidence; feeling of complacency or invincibility.
- Lack of familiarity with laser equipment.
- Improper restoration of equipment following service.
- Manufacturer-installed safety features bypassed.
- Injury from plasma and collateral radiation.
- Failure to follow standard operating procedures.

Laser Operators

- The laser must only be operated by personnel who have been appropriately trained in laser safety and in the specific laser procedures to be performed. Laser operators must be authorized by the Principal Investigator to do the work.
- The laser must be under the direct supervision of an individual knowledgeable in laser safety.
- Lab personnel may operate the laser system only with the approval of their supervisor.
- It is the responsibility of the Research Director or Lab Manager to ensure that all personnel working in the laser area are informed about the potential hazards of the equipment.
- The laser must have only diffusely reflecting materials in or near the beam path, where feasible. Avoid wearing metal jewelry (wristwatches in particular), while working with laser beams and electronic components.
- Never stare directly into a laser beam, regardless of the class of the laser, even if eye protection is worn. Use an indirect means (beam card, photodetector, etc.) to observe the beam.
- Use the buddy system when working with high voltage equipment. All personnel working with this equipment shall be trained in cardiopulmonary resuscitation (CPR). If defibrillation equipment is available in the proximity, all personnel shall know the location, have access to and be trained in the use of the defibrillator. Contact EH&S for CPR and defibrillator training
- Give sufficient attention to non-beam hazards to prevent injuries and illnesses which could be caused by them.
- Be aware of plasma and collateral radiation.

Limit Access

- Spectator access to lasers must be limited. It is best to exclude visitors from laboratories in which Class 3B or Class 4 lasers are in use.
- Windows and doorways must be covered or restricted in such a manner as to reduce the transmitted laser radiation below the MPE.
- Class 3B and Class 4 lasers must be surrounded by light absorbing curtains, usually black, which must be fire resistant.
- An activated laser must not be left unattended without appropriate safeguards such as illuminated warning signs, blackout curtains, and door interlocks.
- Class 4 lasers must have a system for entryway safety controls such as doorway interlock mechanisms.
- The laser or laser system MUST be disabled by means of a key when not in use, to prevent use by untrained operators.
- A shield must be provided around light sources used to pump a laser to prevent injury from flying glass in the event of a light source explosion.
- Properly secure lasers and the optical components used with them to the table to avoid eye injuries due to the inadvertent movement of such items during an experiment.

- Engineering controls (interlocks, beam stops, signs, activation warning systems, etc.) are the first line of defense against laser hazards and should be used to their full advantage. These control measures must not be defeated.
- Laser beams should always be positioned above or below the normal eye level of a standing or seated person.

Outdoor Use and Demonstration

- Laser beams must not be transmitted out of doors or beyond UCLA premises without review and written permission from the UCLA Laser Safety Committee or EH&S.
- Only Class 1 and Class 2 lasers may be used for general public demonstration, display, or entertainment without prior approval. Class 3B and Class 4 lasers used for any of these purposes must obtain an approval from the UCLA Laser Safety Committee or the LSO.

Education and Training

Education and training must be provided for operators and anyone performing maintenance on lasers. All such staff must successfully complete adequate training prior to commencement of work with the laser. The training should be commensurate with the level of potential hazard. Personnel should be informed of the potential hazards of each laser by their supervisor or the Principal Investigator.

Only appropriately trained individuals should perform laser maintenance or repair. The Principal Investigator is responsible for ensuring that service personnel from outside vendors are appropriately trained and that the service is performed in accordance with the UCLA Laser Safety Program.

Laser Purchase Review

A review must be conducted by EH&S prior to the purchase of a new laser or essential laser components. The purpose of this review is to incorporate the new laser into the inventory system and to specify any special precautions or requirements.

It is the responsibility of the Principal Investigator to notify EH&S of fabricated lasers or any lasers which are acquired from sources outside of UCLA purchasing. The UCLA purchasing department will inform EH&S of all new purchases of Class 3B and Class 4 lasers.

The goal of the purchase review program is to assist the laboratory's laser safety program and to inform the PI of any applicable safety considerations prior to the actual acquisition and use of the laser.

Appendix O: Suppliers for Laser Safety Products

Rockwell Laser Industries
P.O. Box 43010
7754 Camargo Rd.
Cincinnati, Ohio 45243
Telephone: 800-945-2737
Fax: 513-271-1598
www.rli.com

Laser Institute of America
13501 Ingenuity Dr., Suite 128
Orlando, FL 32826
Telephone: 407-380-1553, 800-34-LASER
Fax: 407.380.5588
www.laserinstitute.org

The Kentek Corporation
1 Elm Street
Pittsfield, New Hampshire 03263
Telephone: 800-432-2323
Fax: 603-435-7441
www.kentek-laser.com

Wilson industries, Inc.
123 Explorer Street
Pomona, CA 91768
Telephone: 800-423-4277
Fax: 909-468-3640
www.wilsonindustries.com

Laser Vision USA
595 Phalen Boulevard
St. Paul, MN 55101
Telephone: 800-393-5565
Fax: 651-357-1830
www.lasersafety.com

APPENDIX P: GLOSSARY

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

Aversion response – Closure of the eyelid, eye movement, papillary constriction, or movement of the head to avoid an exposure to a noxious or bright light stimulant. In this standard, the aversion response to an exposure from a bright, visible, laser source is assumed to limit the exposure of a specific retinal area to a 0.25s or less.

Beam – A collection of light/photonic rays characterized by direction, diameter (or dimensions), and divergence (or convergence).

Coherent – A beam of light characterized by a fixed phase relationship (spatial coherence) or single wavelength, i.e. monochromatic (temporal coherence)

Collimated beam – Effectively, a “parallel” beam of light with very low divergence or convergence

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

Divergence – In this standard, the increase in the diameter of the laser beam with the distance from the exit aperture, based on the full angle at the point where the irradiance (or radiant exposure for pulsed lasers) is 1/*e* times the maximum value.

Embedded laser – An enclosed laser that has a higher classification than the laser system in which it is incorporated, where the system’s lower classification is appropriate due to the engineering features limiting accessible emission.

Infrared – In this standard, the region of the electromagnetic spectrum between the long-wavelength extreme of the visible spectrum (about 0.7 µm) and the shortest microwaves (about 1mm).

Laser – A device that produces radiant energy predominantly by stimulated emission. Laser radiation may be highly coherent temporally, spatially, or both. An acronym for Light Amplification by Stimulated Emission of Radiation.

Laser classification – An indication of the beam hazard level of a laser or laser system during normal operation or the determination thereof. The hazard level of a laser or laser system is represented by a number or a numbered capital letter. The laser classifications are Class 1, Class 1M, Class 2, Class 2M, Class 3R, Class 3B, and Class 4. In general, the potential beam hazard level increases in the same order.

Laser pointer – A laser product that is usually hand held that emits a low-divergence visible beam and is intended for designating specific objects or images during discussions, lectures or presentations, as well as for the aiming of firearms or other visual targeting practice. The products are normally Class 1, Class 2, or Class 3R.

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

Laser system – An assembly of electrical, mechanical, and optical components which includes a laser.

Maximum Permissible Exposure (MPE) – The level of laser radiation to which an unprotected person may be exposed without adverse biological changes in the eye or skin.

The highest power or energy density (in W/cm^2 or J/cm^2) of a light source that is considered safe, i.e. that has a negligible probability for creating damage. It is usually about 10% of the dose that has a 50% chance of creating damage under worst-case conditions. The MPE is measured at the cornea of the human eye or at the skin, for a given wavelength and exposure time.

A calculation of the MPE for ocular exposure takes into account the various ways light can act upon the eye. For example, ***deep-ultraviolet light*** causes accumulating damage, even at very low powers. ***Infrared light*** with a wavelength longer than about 1400 nm is absorbed by the transparent parts of the eye before it reaches the retina, which means that the MPE for these wavelengths is higher than for visible light.

In addition to the wavelength and exposure time, the MPE takes into account the spatial distribution of the laser light. Collimated laser beams of ***visible and near-infrared light*** are especially dangerous at relatively low powers because the lens focuses the light onto a tiny spot on the retina. Light sources with a smaller degree of spatial coherence than a well-collimated laser beam lead to a distribution of the light over a larger area on the retina. For such sources, the MPE is higher than for collimated laser beams.

In the MPE calculation, the worst-case scenario is assumed, in which the eye lens focuses the light into the smallest possible spot size on the retina for the particular wavelength and the pupil is fully open. Although the MPE is specified as power or energy per unit surface, it is based on the power or energy that can pass through a fully open pupil (0.39 cm^2) for visible and near-infrared wavelengths. This is relevant for laser beams that have a cross-section smaller than 0.39 cm^2.

Monochromatic light – Having or consisting of one color or wavelength.

Must – The word must is to be understood as mandatory.

Nominal Hazard Zone (NHZ) – The space within which the level of the direct, reflected, or scattered radiation may exceed the applicable MPE. Exposure levels beyond the boundary of the NHZ are below the appropriate MPE.

Optically aided viewing – Viewing with a telescope (binocular) or magnifying optic. Under certain circumstances, viewing with an optical aid can increase the hazard from a laser beam.

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

Pulsed laser – A laser which delivers its energy in the form of a single pulse or a train of pulses. In this standard, the duration of a pulse is less than 0.25 s.

Reflection – Deviation of radiation following incidence on a surface

Shall – The word shall is to be understood as mandatory.

Should – The word should is to be understood as advisory.

Specular reflection – A mirror-like reflection.

Telescope viewing – Viewing an object from a long distance with the aid of an optical system that increases the visual size of the image. The system (e.g. binoculars) generally collects light through a large aperture thus magnifying hazards from large-beam, collimated lasers.

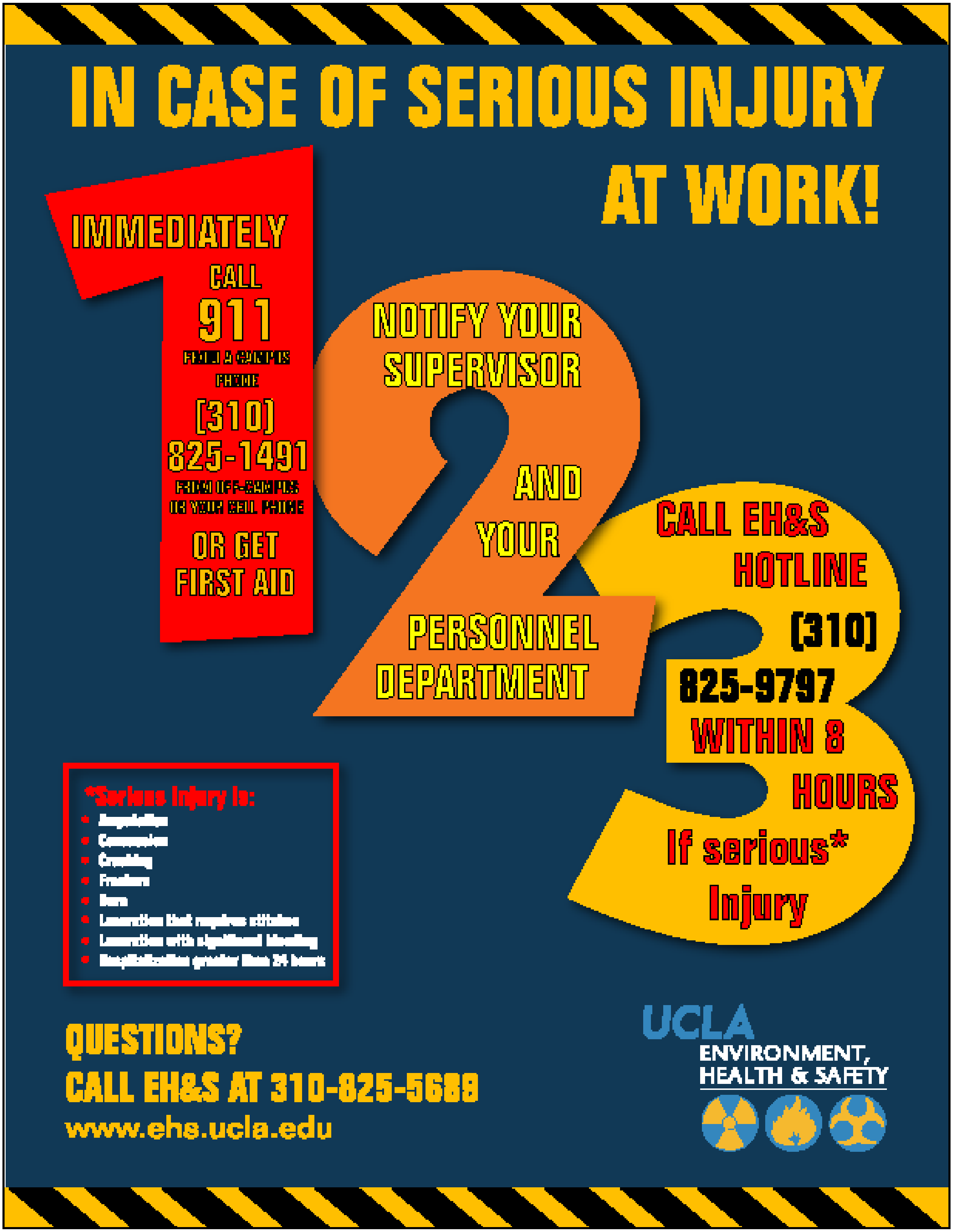
Transmission – Passage of radiation through a medium

Threshold Limit Value (TLV) - of a chemical substance is a concentration level to which it is believed a worker can be exposed day after day for a working lifetime without adverse health effects. The TLV is an estimate based on the known toxicity in humans or animals of a given chemical substance and the reliability & accuracy of the latest sampling and analytical methods.
TLV is defined as a concentration in air, typically for inhalation or skin exposure. Units are in parts per million parts of air (ppm) for gases and in milligrams per cubic meter (mg/m^3) for particulates such as dust, smoke and mist.
TLVs for physical agents include those for noise exposure, vibration, ionizing & non-ionizing radiation exposure and heat & cold stress.

Ultraviolet radiation – In this standard, electromagnetic radiation with wavelengths between 180 nm and 400 nm (shorter than those of visible radiation).

Visible radiation (light) – The term is used to describe electromagnetic radiation which can be detected by the human eye. In this standard, this term is used to describe wavelengths which lie in the range of 400 nm to 700 nm. Derivative standards may legitimately use 380 nm to 780 nm for the visible radiation range.

Wavelength – The distance in the line of advance of a sinusoidal wave from any one point to the next point of corresponding phase (e.g. the distance from one peak to the next).


IN CASE OF SERIOUS INJURY AT WORK!
1
IMMEDIATELY CALL 911
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FROM OFF-CAMPUS OR YOUR CELL PHONE
OR GET FIRST AID
2
NOTIFY YOUR SUPERVISOR
AND YOUR
PERSONNEL DEPARTMENT
3
CALL EH&S HOTLINE
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WITHIN 8 HOURS
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