LASER SAFETY PROGRAM

Wellesley College
106 Central Street
Wellesley, MA 02481

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PREFACE:

The Wellesley College Laser Safety Program will be administered by the Laser Safety Officer (LSO). The LSO is responsible for the establishment and continuing review of all aspects of the program. The LSO, in conjunction with the Laser Supervisors, shall ensure complete compliance with laser safety regulations promulgated by state, federal and local agencies as well as Wellesley College policies and procedures. Copies of the Laser Safety Manual may be requested from either the LSO or Laser Supervisors.

Laser Safety Officer	**Assistant Director of EHS**
Laser Supervisors	**Lab-specific Faculty and Staff**

The Assistant Director of EHS serves as the Laser Safety Officer. The LSO is responsible for providing the services outlined in this program. You may contact the LSO at 781-283-2762. Lab-specific faculty and staff members serve as the Laser Supervisors. The Laser Supervisors are responsible for authorizing laser users and overseeing daily activities involving laser equipment. A list of current laser-related contacts, LSO and Laser Supervisors and their contact information, can be found in Appendix O.

EMERGENCY PHONE NUMBERS

Wellesley College Police: X 5555 24-hour coverage

This call must be the first action in any emergency requiring immediate response. Campus Police will advise by phone and come to the scene. Campus Police will contact emergency services - i.e. call for ambulance, if needed.

HEALTH SERVICES (for students)

Dial 2810

All students must contact or visit Health Services for non-life-threatening medical emergencies. For after hours, contact Campus Police and Campus Police will contact the on-call doctor at Health Services. In all situations, Health Services will guide students for appropriate medical care, including eye exams.

OCCUPATIONAL HEALTH CLINIC (for employees)

Report details of any injury or suspected injury and immediately visit a physician for an eye examination. Laser eye examinations are available at:

BI Deaconess
Occupational Health Clinic
148 Chestnut Street
Needham, MA
(781) 453-3000

The Occupational Health Clinic will guide employees on appropriate medical care, including eye exams.

LASER SAFETY OFFICER:

Assistant Director of EHS X 2762

Report the incident immediately to the LSO

LASER SUPERVISORS:

Lab-specific Faculty and Staff - Consult the lab door for contact information and see Appendix O

Report incident immediately for follow-up action.

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I. INTRODUCTION

The acronym **LASER** stands for **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation. A laser is a device which when energized can emit a highly collimated beam of extremely intense monochromatic electromagnetic radiation. This radiation can be emitted over a wide range of the electromagnetic spectrum from the ultraviolet region through the visible to the infrared region. The range of commonly available lasers is from 200 nanometers to 10.4 micrometers. Laser radiation may be emitted as a continuous wave or in pulses.

Lasers produce nonionizing radiation. The primary mechanism of beam damage for most lasers therefore, is thermal. It should be noted that photochemical damage may also occur when dealing with lasers operating in the ultraviolet region. The intensity of the radiation that may be emitted and the associated potential hazards depend upon the type of laser, the wavelength of the energized beam, and the proposed uses of the laser system.

The safe use of laser systems depends upon the basic principles of safety, which are recognition, evaluation, and control of potential hazards. This program will review laser operations, the associated potential hazards, responsibilities of the laser user community, and the services provided by the LSO and Laser Supervisors to help in the safe use of laser radiation.

II. HAZARD CONTROLS

The hazard controls necessary for the safe use of laser radiation depend upon:

a) the laser classification

b) the environment where the laser is used

c) the laser operating characteristics

d) the persons operating the laser

e) the general population within the vicinity of the laser

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

Hazard Controls (continued)

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

1. Unanticipated eye exposure during alignment
2. Misaligned optics
3. Available eye protection not used
4. Equipment malfunction
5. Improper method of handling high voltage
6. Intentional exposure of unprotected personnel
7. Operator unfamiliar with laser equipment
8. Lack of protection for ancillary hazards
9. Improper restoration of equipment following service
10. Inadvertent beam discharge
11. Insertion of flammable materials into beam path

III. Responsibilities

A. Student Users

Each registered laser user is responsible for:

1. Complying with all requirements of the Wellesley College Laser Safety Program, including annual training* attendance and following SOPs for lasers in the laboratories.

2. Wearing appropriate laser eyewear as necessary.

*Annual, documented laser-specific training must be received from the Principal Investigator/ faculty member supervising the laser's operation or the Laser Supervisor for the lab.

B. Principal Investigators/ Faculty Using Lasers/ Laser Supervisors

Each faculty member utilizing lasers at Wellesley College is responsible for the following:

1. Notifying the LSO of all Class 3b and Class 4 laser systems. This includes notification of transfers and decommissioning of lasers and laser systems.

2. Scheduling for LSO-provided laser safety seminars for new non-student laser workers. Additional training for individual lasers and procedures is expected at the project level in accordance with the equipment Standard Operating Procedure (SOP).

3. Providing the necessary equipment and work environment for the safe use of the project's lasers.

4. Informing all laser workers of the potential hazards associated with the use of the lasers and the applicable safety requirements.

5. Developing and posting standard operating procedures, which include safety aspects, for all Class 3b and Class 4 lasers. SOPs shall be updated by the Laser Supervisor annually and whenever procedures change.

6. Ensuring that all faculty and staff receive laser safety training at least every 3 years.

7. Informing the LSO of any new lasers, significant changes in the current use of lasers, and new workers joining the project.

8. The Laser Supervisor is responsible for all safety and compliance issues as described in the Wellesley College Laser Safety Manual.

9. Maintaining a list of all laser users/workers and their training dates.

C. Laser Safety Officer (LSO)

Detailed information (Appendix O) on the control of laser radiation hazards is available from the LSO. The LSO and Laser Supervisor will provide services to assist authorized laser users in maintaining a comprehensive laser safety program. These services will include training, signage, review of engineering controls and personal protective equipment, and incident follow up.

D. Radiation Safety Committee

The Radiation Safety Committee oversees safe use of lasers at the Science Center. Committee members act as a conduit for distributing laser-related information to their respective departments and notifying the Committee regarding department specific laser-related activities. Members will discuss periodic updates to the laser safety program and may be asked to assist in laser-related incident investigation.

IV. Annual EHS Laser Inspection

EHS will comprehensively inspect laser laboratories annually. Additional inspections may be conducted at the discretion of the LSO, for example, as a component of a laser incident investigation. Laser laboratory inspections will utilize the inspection checklist found in **Appendix H**. Inspection points resulting in an "Unsatisfactory" notation will be corrected promptly to the satisfaction of the Laser Safety Officer. All laser lab inspection documents will be kept on file by the LSO at the Distribution Center and will be distributed electronically to the appropriate laser supervisors for the laboratory, to be kept on file in hard copy form or electronically.

V. Laser Classifications and Safety Controls

The American National Standards Institute (ANSI) has established a laser hazard classification system in publication ANSI Z136.1-2014. The summary of the hazard(s) and engineering controls associated with each class of laser can be found in **Appendix B.**

VI. General Safety Procedures

1. Do not work alone.

2. Do not work with or near a laser unless you have been authorized to do so.

3. Do not enter a room or area where a laser is being energized unless authorized to do so.

4. Before energizing a laser, verify that prescribed safety devices for the unit are being properly employed. These may include opaque shielding, non-reflecting and/or fire-resistant surfaces, goggles and/or face shields, door interlocks, and ventilation for toxic material.

5. Make sure that a pulsed laser unit cannot be energized inadvertently. Discharge capacitors and turn off power before leaving the laser unit unattended.

6. Don't stare directly into the laser beam. Use appropriate eyewear during beam alignment and laser operation. Beam alignment procedures should be performed at lowest practical power levels.

7. Control the access to the laser facility. This can be done by clearly designating trained personnel to have access to the laser room. Locking the door and installing warning lights and signs on the outside door can control access.

8. Never leave the laser unattended when it is in operation.

10. Remove any jewelry to avoid inadvertent reflections.

11. Prior to the construction of a new laboratory or the renovation of an existing laboratory intended to house Class 3b or Class 4 lasers, the LSO must be notified. Renovation and construction plans must include laser safety features. Construction requirements may mandate installation of safety features such as illuminated laser in use signage, laser curtains, grounding, interlocks, emergency power offs, optical tables and laser eyewear storage as determined by the Laser Safety Officer.

12. Class III B and Class 4 lasers may be moved between laser labs that have the proper controls in place. Notify the LSO prior to moving a laser system.

VII. Laser Pointer Precautions

All Class 2, 2M or 3R laser pointers used for presentations shall be operated under the following guidelines. No laser pointers above a Class 3R (5mW power output) are permitted for regular use at Wellesley College. The use of any higher class laser pointer requires LSO approval prior to use.

To ensure safety, the following guidelines must be followed:

1. No person shall intentionally stare into the beam of a laser pointer.
2. No person shall intentionally aim the pointer at him or herself or at another person.
3. The beam shall be directed towards the screen and away from the audience.
4. The beam shall be turned off when not in use.
5. Mirror-like surfaces shall be avoided when using the beam.

Green Pointers:

A new laser pointer is on the market which is a frequency doubled Nd:YAG laser. The output beam is 532 nm, with a blocked infrared beam at 1064 nm. These pointers are exceptionally bright to the human eye, and for safety it is critical to ensure that the invisible 1064 nm beam blocking filter is in place.

VIII. Laser Incidents

In the event that a laser worker suspects they have been exposed to excessive levels of laser radiation, act quickly and follow the steps in **Appendix N.**

IX. Experimental Procedures/ High Powered Lasers

Refer to **Appendix J.**

X. Visitors Policy

In certain circumstances, non-Wellesley affiliates may be admitted to the laser laboratory to observe demonstrations. Visitors will be given basic, documented laser training by the appropriate Laser Supervisor and will be provided with appropriate eye protection if a laser is in use.

- The Laser Supervisor shall accompany the visitor
- The laser shall be fully enclosed

XI. Use of Class 3b/Class 4 Lasers in a Classroom Presentation/Demonstration

The use of Class 3b and Class 4 lasers outside of a designated laser laboratory is prohibited. They are not to be taken into the classrooms for any purpose.

Appendix A

Glossary

The definitions of the terms listed below are based on a pragmatic rather than basic approach. The terms defined are therefore limited to those actually used in this program and its appendices and are in no way intended to constitute a dictionary of terms used in the laser field as a whole.

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

accessible emission limit (AEL). The maximum accessible emission level permitted within a particular class.

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

average power. The total energy imparted during exposure divided by the exposure duration.

aversion response. Movement of the eyelid or the head to avoid an exposure to a noxious stimulant or bright light. It can occur within 0.25s including the blink reflex time.

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

beam diameter. The distance between diametrically opposed points in that cross-section of a beam where the power per unit area is I/e (0.368) times that of the peak power per unit area.

coherent. A light beam is said to be coherent when the electric vector at any point in it is related to that at any other point by a definite, continuous function.

continuous wave (cw). The output of a laser which is operated in a continuous rather than a pulsed mode. In this program, a laser operating with a continuous output for a period of 0.25s is regarded as a CW laser.

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

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

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. See Figure 10.

divergence. The increase in the diameter of the laser beam with distance from the exit aperture. The value gives the full angle at the point where the laser energy or irradiance is 1/e (36.8%) of the maximum value. For the purposes of this program, divergence is taken as the full angle, expressed in radians of the beam diameter measured between those points which include laser energy or irradiance equal to 1/e of the maximum value of the angular extend of a beam which contains all the radius vectors of the polar curve of radiant intensity that have length rated at 36.8% of the maximum. Sometimes this is also referred to as beam spread.

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

electromagnetic radiation. The flow of energy consisting of orthogonally vibrating electric and magnetic fields lying transverse to the direction of propagation. X-ray, ultraviolet, visible infrared, and radio waves occupy various portions of the electromagnetic spectrum and differ only in frequency and wavelength.

irradiance (E) (at the point of a surface). Quotient of the radiant flux incident on an element of surface containing the point at which irradiance is measured, by the area of that element. Units are watt per square centimeter (W/cm^2).

joule(J). A unit of energy. 1 joule = 1 watt per second.

maximum permissible exposure (MPE). The level of laser radiation to which a person may be exposed without hazardous effect or adverse biological changes in the eye or skin. The criteria for MPE for the eye and skin are detailed in **Appendix E.**

nominal hazard zone (NHZ). The nominal hazard zone describes the space within which the level of direct reflected or scattered radiation during normal operation exceeds the applicable MPE. Exposure levels beyond the boundary of the NHZ are below the appropriate MPE level.

laser. A device which produces an intense, coherent, directional beam of light by stimulating electronic or molecular transitions to lower energy levels. An acronym for Light Amplification Stimulated by Emission of Radiation.

limiting aperture. The maximum diameter of a circle over which irradiance and radiant exposure can be averaged.

nominal ocular hazard distance (NOHD). The distance along the axis of the unobstructed beam from the laser to the human eye beyond which the irradiance or radiant exposure during normal operation is not expected to exceed the appropriate MPE.

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

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

pupil. The variable aperture in the iris through which light travels to the interior of the eye.

Q-switch. A device for producing very short (<30ns) high power pulses by means of a Q-switch.

Radian (rad). A unit of angular measure equal to the angle subtended at the center of a circle by an arc whose length is equal to the radius of the circle. 1 radian = 57.3 degrees; 2π radians = 360 degrees.

radiance (L). Radiant flux of power output per unit solid angle per unit area. Unit: Watts per centimeter squared per Steradian ($W/cm^2/sr$).

radiant energy (Q). Energy emitted, transferred or received in the form of radiation. Unit: joule (J).

radiant exposure (H). Surface density of the radiant energy received. Unit: joules per centimeter squared (J/cm^2).

radiant flux. Power emitted, transferred or received in the form of radiation. Unit: watt (W). Also called *radiant power*.

specular reflection. A mirror-like reflection. See Figure 9

Appendix B

The American National Standards Institute (ANSI) has established a laser hazard classification system in publication ANSI Z136.1-2014. The following is a summary of the hazard(s) and engineering controls associated with each class of laser:

LASER Class	Hazard Description	Safety Controls	Power (mW)
1	**Cannot produce hazardous radiation.**	No safety controls are necessary.	< 1mW
2	**Continuous intrabeam exposure damages the eye. Momentary intrabeam exposure (< 0.25 seconds) is not damaging to the eye. Visible radiation only.**	Do not stare continuously into laser source. Never point at an individual's eye unless a useful purpose exists and permissible limit is not exceeded.	< 1mW
2M	**Continuous intrabeam exposure damages the eye. The accessible radiation shall not exceed Class 1. AEL for an exposure duration < 10^{3} seconds.**		
3R	**Eye damage may occur if the beam is viewed directly or with optical instruments.**	Do not aim at an individual's eye. Enclose as much of beam path as possible. Use proper laser eye protection. Remove all unnecessary mirror-like surfaces. Place beam path well above or below eye level. Permit only experienced personnel to operate laser.	1mW-4.99mW
3B	**Eye damage will occur for direct, momentary intrabeam exposure or exposure to specular reflections.**		5mW-499mW
4	**Eye and skin damage will occur for direct, momentary intrabeam exposure or exposure to specular or diffuse reflections. Potential fire hazard.**	Follow all Class 3 safety controls. Beam shutters, polarizers, and filters should always be used. Backstops should be diffusely reflecting, composed of fire-resistant materials. Operate within a controlled workspace.	500mW+

Certified laser manufacturers are required to label their products as to the Class type as of September 19, 1985 (21 CFR Part 1040). Information regarding appropriate eyewear for a specific laser may be obtained from the manufacturer at time of purchase. Engineering Control measures for laser classifications (ANSI Z136.1-2014) – **Appendix C** Required caution and danger signs – **Appendix K.**

APPENDIX C

ENGINEERING CONTROL MEASURES BY LASER CLASS

Table 2: Engineering Control Measures for the Seven Laser Classes. American National Standard Z136.1-2014

Engineering Control Measures	Classification						
	1	1M	2	2M	3R	3B	4
Protective Housing (4.4.2.1)	X	X	X	X	X	X	X
Without Protective Housing (4.4.2.1.1)	LSO shall establish Alternative Controls						
Interlocks on Removable Protective Housings (4.4.2.1.3)	∇	∇	∇	∇	∇	X	X
Service Access Panel (4.4.2.1.4)	∇	∇	∇	∇	∇	X	X
Key Control (4.4.2.2)	—	—	—	—	—	•	•
Viewing Windows, Display Screens and Diffuse Display Screens (4.4.2.3)	Ensure viewing limited < MPE						
Collecting Optics (4.4.2.6)	X	X	X	X	X	X	X
Fully Open Beam Path (4.4.2.7.1)	—	—	—	—	—	X NHZ	X NHZ
Limited Open Beam Path (4.4.2.7.2)	—	—	—	—	—	X NHZ	X NHZ
Enclosed Beam Path (4.4.2.7.3)	Further controls not required if 4.4.2.1 and 4.4.2.1.3 fulfilled						
Area Warning Device (4.4.2.8)	—	—	—	—	—	•	X
Laser Radiation Emission Warning (4.4.2.9)	—	—	—	—	—	•	X
Class 4 Laser Controlled Area (4.4.2.10 and 4.4.3.5)	—	—	—	—	—	—	X
Entryway Controls (4.4.2.10.3)	—	—	—	—	—	—	X
Protective Barriers and Curtains (4.4.2.5)	—	—	—	—	—	•	•

LEGEND:
X Shall
• Should
— No requirement
∇ Shall if enclosed Class 3B or Class 4
NHZ Nominal Hazard Zone analysis required

APPENDIX D

LASER RADIATION HAZARDS

The basic hazards associated with the use of lasers are categorized as follows:

1. Laser Hazards

Eye: Corneal or retinal burns are possible from acute exposure. Location and extent of injury is dependent upon wavelength and classification of laser. Corneal opacities (cataracts) or retinal injury may be possible from chronic exposures to excessive levels. Eye hazards are easily controlled with the use of appropriate laser safety eyewear, or other engineering safety controls.

Skin: Skin burns are possible from acute exposure to high levels of laser radiation in the infrared spectral region. Erythema (sunburn), skin cancer, and accelerated skin aging are possible in ultraviolet wavelength range.

2. Electrical Hazards

The most common hazard encountered in laser use is electric shock. Potentially lethal electrical hazards may be present especially in high-powered laser systems.

3. Chemical Hazards

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

4. Fire Hazards

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

5. Associated Hazards

Associated hazards can include cryogenic coolant hazards, excessive noise from high-powered systems, and radiation from high-voltage power supplies.

APPENDIX E

EYE PROTECTION AND MAXIMUM PERMISSIBLE EXPOSURES

Laser irradiation of the eye may cause damage to the cornea, the lens, or the retina, depending on the wavelength of the light and the energy absorption characteristics of the ocular media (see Fig. 1). Lasers can cause biological damage by depositing heat energy in a small area, or by photochemical processes. Infrared, Ultraviolet, and Visible U.V. radiation are capable of causing damage to the eye.

1. **Retinal Damage--<u>Visible and Near Infrared</u> (Spectral Region 400-1400nm)**

   Visible wavelengths penetrate through the cornea to be focused on a small area of the retina, the fovea centralis (see Fig. 2). This process greatly amplifies the energy density and increases the potential for damage. Lesions may form on the retina as a result of local heating of the retina subsequent to absorption of the light.

2. **Corneal Damage--<u>Infrared</u> (Spectral Region 1.4 to 1000nm)**

   The Cornea of the eye is opaque to infrared radiation (see Fig. 3). The energy in the beam is absorbed on the surface of the eye and damage results from heating of the cornea. Excessive infrared exposure causes a loss of transparency or produces a surface irregularity on the cornea.

3. **Corneal Damage--<u>Ultraviolet</u> (Spectral Region 200-400nm)**

   The cornea of the eye is also opaque to ultraviolet radiation. As with infrared radiation, the energy of the beam is absorbed on the surface of the eye and corneal damage results (see Fig. 3 and 4). Excessive ultraviolet exposure results in photokeratitis (Welder's Flash), photophobia, redness, tearing, conjunctival discharge, and stromal haze. There is a 6-12 hour latency period before symptoms of photochemical damage appear.

4. **Other Ocular Damage**

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

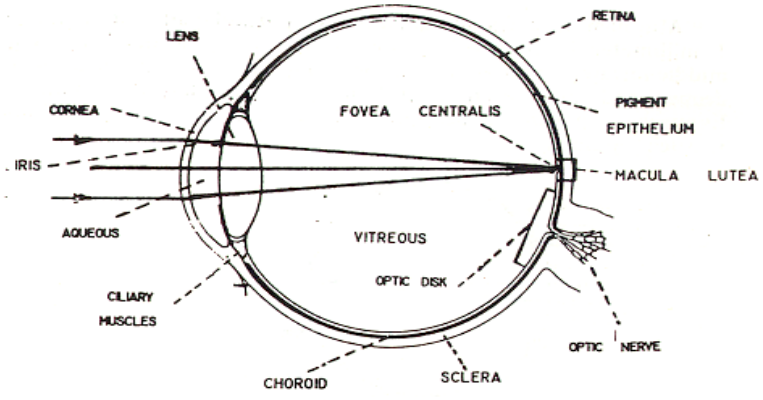


Figure 1. Schematic diagram of the human eye showing structures of interest. Parallel rays of light can be focused to a very small area on the retina when the eye is relaxed.

Figure 2. Absorption sites of visible and near infrared radiation (400-1400nm).

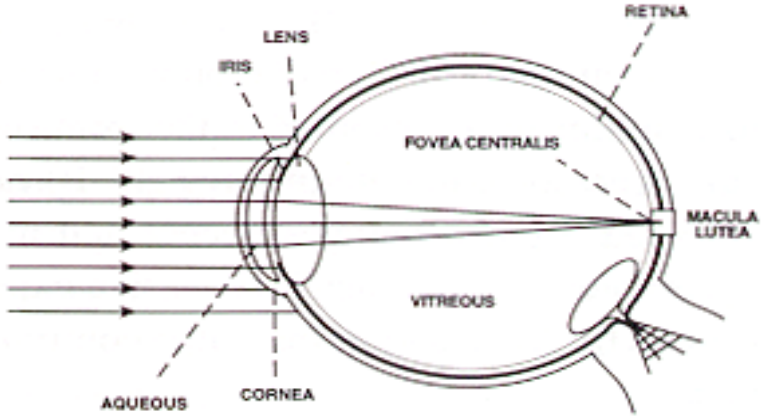


Figure 3. Absorption sires of middle, far-infrared radiation (1400nm-1mm) and middle ultraviolet radiation (180nm-315nm).

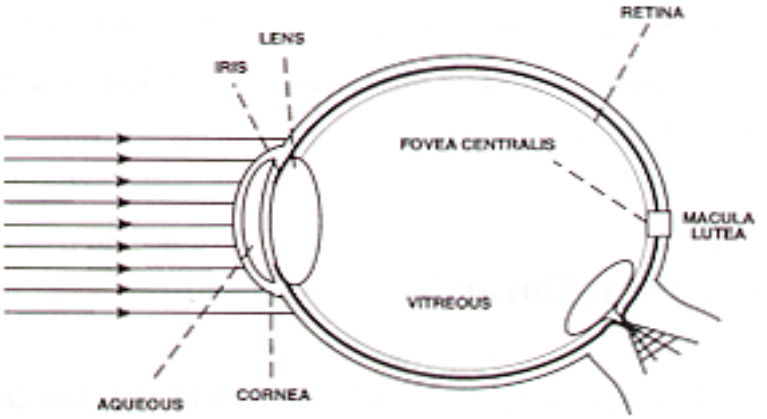
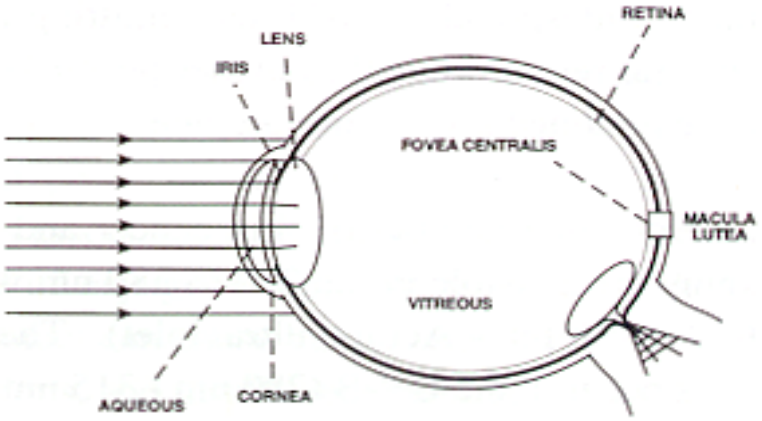


Figure 4. Absorption sites of near ultraviolet radiation (315nm-390nm).



5. Maximum Permissible Exposure (M.P.E.)

On the basis of retinal damage thresholds and concentrations of light by the lens,

maximum permissible exposure limits have been recommended by the American National Standards Institute (ANSI Z136.1-2014). The M.P.E. values for visible light are based on a pupil diameter of 7mm, which is considered to the maximum opening of the iris of the eye. For other wavelengths, the incident laser energy is averaged over a 1mm diameter circle. The M.P.E. values are below known hazardous levels. However, the M.P.E. values that appear in the table may be uncomfortable to view. Thus, it is good practice to maintain exposure levels as far below the M.P.E. values as practical.

6. Protective Eyewear

ANSI Z136.1-2014 requires that protective eyewear be available and worn whenever hazardous conditions may result from laser radiation or laser related operations.

The eye may be protected against laser radiation by the use of protective eyewear that attenuates the intensity of laser light while transmitting enough ambient light for safe visibility (luminous transmission). The ideal eyewear provides maximum attenuation of the laser light while transmitting the maximum amount of ambient light. No single lens material is useful for all wavelengths or for all radiation exposures. In choosing protective eyewear, careful consideration must be given to the operating parameters, M.P.E.s, and wavelength. The LSO will recommend the appropriate laser safety eyewear during the laser training process. A list of laser safety eyewear manufacturers can be found in **Appendix L.**

Note (1): Persons working with lasers emitting in the visible region are often unwilling to wear protective eyewear during alignment procedures due to the inability to see the beam. Laser alignment goggles are available which provide acceptable protection during reduced power alignment procedures while allowing an outline of the beam to be seen.

Note (2): Appropriate eyewear information may be required for a particular laser from the manufacturer at the time of purchase. Insight as to proper and reasonable eye protection may also be obtained from the LSO. It is recommended that the LSO evaluate all protective eyewear.

Skin Exposure and Maximum Permissible Exposures

Acute exposure of the skin to large amounts of energy from the laser may cause burning of the skin. These burns are similar to thermal or radiant (sun) burns. The incident radiation is converted to heat which is not dissipated rapidly enough due to poor thermal conductivity of the tissue. The resulting local temperature rise causes denaturation of tissue protein. Injury of the skin depends on the wavelength of laser light, exposure time, and degree of skin pigmentation. Skin carcinogenesis may occur at some specific ultraviolet wavelengths (290-320nm).

APPENDIX F

Electrical Hazards

There have been several electrocutions in the U.S. from laser-related electrical accidents. These accidents could have been prevented. Contact the LSO if you have any questions concerning electrical safety.

The following are general guidelines to prevent electrical shock:

1. Avoid wearing rings, metallic watchbands and other metallic objects.

2. When possible, only use one hand when working on a circuit.

3. Assume that all floors are conductive when working with high voltage.

4. Check that each capacitor is discharged, shorted and grounded before allowing access to the capacitor area.

5. Inspect capacitor containers for deformities or leaks.

6. Provide such safety devices as appropriate rubber gloves and insulating mats.

7. Do not work alone.

APPENDIX G

Standard Operating Procedure Template for Laboratory Safety

SOP Author:	Implementation Date:
Department:	Last Reviewed/Updated Date:
SOP Title:	Reviewed by:
Location(s):	

1. Purpose/Background
2. Scope
3. Process or Experiment Description
4. Procedures

   To address procurement, inventory, storage, use, monitoring, transport, security, and special handling procedures and work practices.

   List steps to be followed in performing the procedure and the required precautions to avoid harm.

Task	Potential Hazard	Precautions
1.		
2.		

   a. Decontamination Procedures
   b. Emergency Procedures
   c. Use of ventilation/engineering controls
   d. Personal Protective Equipment to be used
   e. Waste Disposal

5. Training

   Who receives training, who will provide training, how often, material covered

6. References
   a. Standards, Supplementary Documents, Websites

APPENDIX H

LASER LABORATORY INSPECTION CHECKLIST

Lab Safety Inspection Checklist Description

(1-5) General Laser Safety

1. Security Doors are closed & locked when unoccupied; closed when person is physically in that specific room.
2. No evidence of food, drink, smoking or cosmetics in lab.
3. All personnel laser safety training is current. The recommendation is for annual training for students and training every 3 years for faculty and staff.
4. All laser incidents/ injuries are reported to the LSO.
5. Laboratory housekeeping is adequate.

(6-9) Records

6. There is a current SOP for every Class 3b and Class 4 laser system.
7. All Class 3b and Class 4 lasers are registered with LSO prior to or immediately upon receipt, accounted for, and inventory is current.
8. LSO is notified prior to transferring a laser to another professor or institution.
9. LSO is notified prior to decommissioning or disposing of a laser.

(10-17) Facilities and Equipment

10. Safety equipment unobstructed.
11. Egress unobstructed.
12. Exits are identifiable.
13. Showers & eyewashes are inspected annually & tagged.
14. Fume hoods are inspected annually, certified & tagged.
15. Fire extinguishers are inspected annually & tagged.
16. Illuminated “Laser in Use” light(s) are present and functional for class 4 lasers.
17. Emergency power off button(s) are present, labeled, functional and unobstructed.

(18-25) Postings. Signs & Labels

18. Emergency contact flip chart posted.
19. Laser Safety Manual available electronically.
20. “No eating, drinking, smoking” sign posted and “No Food” labels on applicable freezers/ refrigerators/ microwaves.
21. Applicable ANSI Visible and/or Invisible Laser Radiation” sign posted on door(s) for Class 3b and Class 4 lasers.
22. Warning label visible on housing/ control panel with laser class.
23. Advisory label on removable housing, repeated every 3 meters.
24. Aperture label applied at beam port(s)
25. Warning labels applied to all Class 3b or Class 4 lasers.

(26-32) PPE & Work Practices

26. Lab has adequate number and type of laser safety eyewear for all laser users. Eyewear is worn during laser operation.
27. Laser equipment is only installed in an area that has been previously designed or approved to support such equipment.
28. All laser safety equipment (laser curtains, films, etc.) conforms to the laser lab specification approved by the LSO.
29. Laser safety interlocks are not overridden without LSO approval.
30. Reflective materials are removed from beam path.
31. Laser equipment is secured to optical table.
32. Lasers are not used with malicious intent to cause injury or damage.
33. Laser equipment is not left operating in an unattended space without authorization.

APPENDIX I
Additional Laser Safety Tips

1. Position the beam path well above or below eye level. Enclose as much of the beam path as possible.
2. Securely fasten all mountings in the beam path (mirrors, prisms, beam stops, etc.). Securely fasten the laser itself.
3. Use beam shutters and laser output filters to reduce the beam power when the full output power is not required.
4. Keep extraneous items out of the beam path, particularly reflective objects(e.g. watches, rings, belt buckles) that may cause specular reflections. Jewelry should never be worn while working with laser systems.
5. Indicate with a warning light when the laser is in operation.

APPENDIX J

Experimental Procedures

It is the faculty's responsibility to provide their students with written procedures that ensure safe and proper laser operation by students at all times during experiments

Specific Precautions for High-Powered Pulsed Lasers

1. If safety interlocks are used as a means of control, they should be constructed so that unauthorized or transient personnel are denied access to the facility while the laser power supply is charged and capable of firing.

2. Laser electronic-firing systems should be designed so that accidental pulsing of a stored charge is avoided. The design should incorporate a fail-safe system.

3. An alarm system including muted sound, flashing lights (visible through laser safety eyewear) and a countdown procedure should be used once the capacitor banks begin to charge.

4. Walls and ceilings should be painted with nonreflective paint to produce a diffuse surface. Diffuse black is preferred in the target area, and a light color in the surrounding area to maximize the lighting distribution from general lighting fixtures.

5. Solid-state lasers should be operated by remote control firing with television monitoring, if feasible. This eliminates the need for personnel to be physically present in the same room. An alternative is to enclose the laser, the associated beam, and the target in an appropriate light-tight enclosure.

APPENDIX K

ANSI Z136.1 REQUIRED LASER CAUTION AND DANGER SIGNS LASER EXPOSURE PICTOGRAMS

***Labels can be obtained through contacting the Laser Safety Officer:**

Figure 5: Sample ANSI Z535.2 compliant warning sign for Class 2, Class 2M, and Class 3R lasers. *ANSI Laser Safety Standard, 2014*

Figure 6a: Sample ANSI Z535.2 compliant warning sign for Class 3B laser controlled areas. ***Laser Safety Industries, 2016***

Figure 6b: Sample ANSI Z535.2 compliant warning sign for Class 3B and Class 4 laser controlled areas. ***ANSI Laser Safety Standard, 2014***

Figure 7: Sample ANSI Z535.2 compliant Class 4 laser controlled area danger sign format. ***ANSI Laser Safety Standard, 2014***

Radiation Pictograms

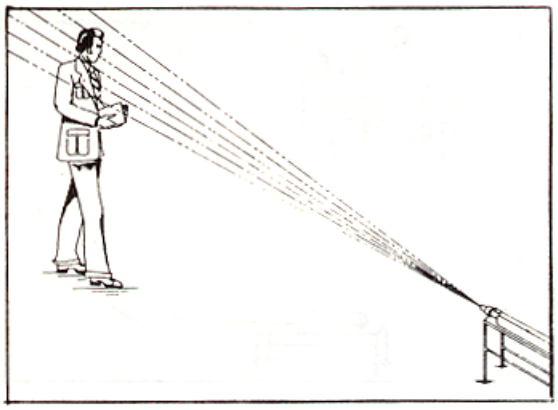


Figure 8: Direct intrabeam exposure.

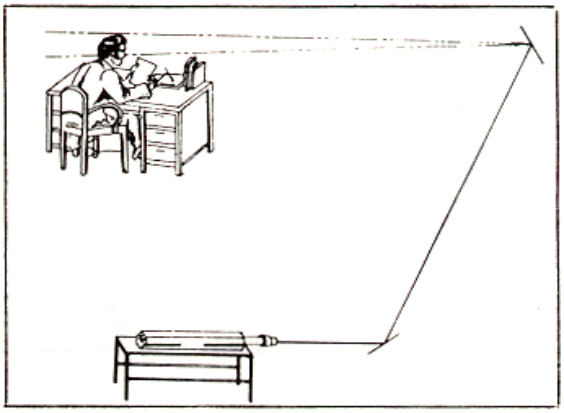


Figure 9: Specular reflections

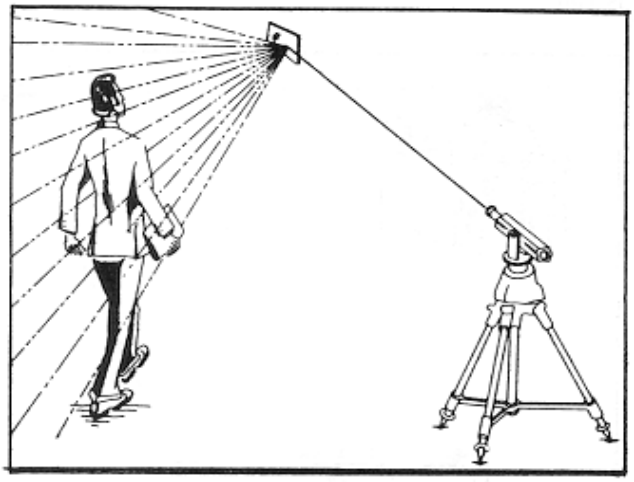


Figure 10: Diffuse reflections

APPENDIX L

LIST OF LASER PROTECTIVE EYEWEAR MANUFACTURERS OR VENDORS

American Allsafe Co.
99 Wales Ave.
Tonawanda, NY 14150
(800) 231-1332

American Optical Company
Safety Products Group
14 Mechanic St.
Southbridge, MA 01550
(617) 765-9711

Ealing Electro-Optics, Inc.
New Englander Industrial Park
Holliston, MA 01746
(508) 429-8370

Edmund Scientific Co.
101 E. Glouster Pike
Barrington, NJ 08007-1380
(609) 547-3488

Energy Technology, Inc.
PO Box 1038
San Luis Obispo, CA 93406
(805) 544-7770

Engineering Technology Institute
601 Lake Air Drive, Suite 1
Waco, TX 76710
(800) 367-4238

Fish-Schurman Corp.
PO Box 319
New Rochelle, NY 10802
(914) 636-1300

General Scientific Equipment Co.
525 Spring Garden
Philadelphia, PA 19123
(215) 922-5710

Kentek Corporation
32 Broardway Street
Pittsfield, NH 03263
(800) 432-2323
www.kenteklaserstore.com

Omicron Eye Safety Corp.
73 Main Street
Brattleboro, VT 05301
(802) 257-7363

Optical Coating Laboratory, Inc.
2789 North Point Parkway
Santa Rosa, CA 95407-7397
(707) 525-7709

Phase-R Co.
Box G-2
New Durham, NH 03855
(603) 869-3800

Fred Reed Optical
PO Box 27010
Albuquerque, NM 87125-7010
(800) 545-0912

Rockwell Laser Industries
7754 Camargo Road
Cincinatti, OH 45243
(513) 271-1568

U.S. Laser Corp.
PO Box 609
825 Windham Ct. N.
Wychoff, NJ 07481
(201) 848-9200

U.V.P., Inc.
PO Box 1501
San Gabriel, CA 91778
(818) 285-3123

UVEX Safety, Inc.
10 Thurber Blvd.
Smithfield, RI 02917
(800) 343-3411

Wilson Industries
South El Monte, CA
(818) 444-7781

APPENDIX M

MASSACHUSETTS CLASS 3B / CLASS 4 LASER REGISTRATION APPLICATION

TO BE SUBMITTED ONLY BY THE LSO

LASER REGISTRATION APPLICATION

(Only Class 3b and Class 4 need be Registered)

MASSACHUSETTS DEPARTMENT OF PUBLIC HEALTH

RADIATION CONTROL PROGRAM

www.mass.gov/dph/rcp

SEND APPLICATIONS TO:

Schrafft Center, Suite 1M2A

529 Main Street, Charlestown, MA 02129

Phone: (617)-242-3035 Fax: (617) 242-3457

Email: RadiationControl@state.ma.us

☐ NEW

☐ AMENDMENT

☐ RENEWAL

☐ DEMONSTRATION

If Applicable, Laser Registration Number: _____

MAILING ADDRESS

Legal Name of Business / Facility / Individual:

_____

Mailing Address: _____

City, State & Zip: _____

REGISTRATION CONTACT PERSON

Contact Person: _____

Phone: _____ Fax: _____

Email: _____

LASER LOCATION (if different than Mailing Address)

(NOTE: Submit separate application for each additional laser location)

Physical Address: _____

_____

City, State & Zip: _____

Phone: _____

Date(s) of Use: _____
(Out-of-State Only)

LASER SAFETY OFFICER*

LSO Name: _____

Address: _____

(if different than above) _____

City, State & Zip: _____

NATURE of LASER USE (i.e., facility type)

☐ **Medical/Dental** ☐ **Veterinary** ☐ **Academic**	☐ **Manufacturer (i.e., make & sell lasers)** ☐ **Industrial (i.e., non-medical use)** ☐ **Entertainment (e.g., laser light show)**** ☐ **Dealer / Distributor (i.e., sell lasers)**	Phone: _____ Fax: _____ Email: _____

***** Submit LSO qualifications to include education, training, and/or experience for new registrations or LSO change.

****** A copy of your valid FDA and/or FAA variance must be submitted with this application.

Safety Procedures: By checking the boxes below, you agree that you will abide by the required safety procedures at each facility. Each box **must** be checked or the application will be considered incomplete.

Refer to applicable volumes in ANSI Z136 for proper guidance.

- ☐ Use of proper protective eyewear.
- ☐ Proper signage, labeling, posting, and barriers.
- ☐ Operating and safety procedures and operator's manual readily available.

Required for Medical Use Lasers: As a licensed practitioner of the healing arts, I do hereby affirm that I am associated with this applicant and provide supervision to non-board approved practitioners[+] administering laser radiation to human beings. I understand a practitioner's use of a laser is limited to his/her scope of professional practice as determined by the appropriate licensing board.

Signature of Licensed Practitioner***	Massachusetts License No.	Massachusetts State Board Name (e.g., Board of Registration in Medicine, or "BORIM")	Date

Typed or Printed Name

*** The signature of the administrator, President, Chief Executive Officer (CEO) will be accepted in lieu of a licensed practitioner's signature if the facility is a licensed hospital or medical facility with more than one licensed practitioner who may direct the operation of radiation machines.

Laser Safety Officer: I hereby accept the responsibilities of Laser Safety Officer as outlined in 105 Code of Massachusetts Regulations §121.000. (Submit qualifications to include education, training, and/or experience for new registrations or LSO change.)

Signature of Laser Safety Officer	Typed or Printed Name	Date

Certification: I certify that I have read and understand the applicable rules and regulations, and agree to comply with them. I understand that it is a violation of Massachusetts laws to submit any false or fraudulent information or documents in order to obtain a registration. All information I have provided on this application is true, correct, and complete to the best of my knowledge.

Signature of applicant or person duly authorized to act on behalf of applicant (e.g., President, CEO, Partner, Owner, etc.)	Typed or Printed Name	Date

[+] Non-board approved practitioners are those whose 'scope of practice', per their respective 'board of registration', does not include the use of lasers.

INVENTORY of CLASS 3B and 4 LASERS

#	Manufacturer	Model	Class (3B or 4)	Serial Number	Mode [1]	Medium [2]	Use [3]
1							
2							
3							
4							
5							
6							
7							

[1,2,3] Please refer to the supplement for 'Mode', 'Medium', and 'Use' when filling out the Class 3B and 4 inventory table

INVENTORY CONTINUED (i.e., Operating Parameters)

#	Max. Wavelength (nm)	Tunable (Y/N)	Beam Diameter (mm)[#]	Beam Divergence (mrad)[#]	Max. Pulse Repetition Freq. (Hz)[#]	Min. Pulse Duration(s)[#]	Max. Joules per Pulse[#]	Average Pulsed Power (mW or mJ)	Continuous Wave Max. Power (mW)
1									
2									
3									
4									
5									
6									
7									

[#] Optional information to be submitted

Supplementary information for INVENTORY table

1 – Mode	2 - Medium	2 – Medium (cont.)	2 – Medium (cont.)	2 – Medium (cont.)
Continuous Wave	Agil	DPSS – Nd:YAG	InGaAs	Sm:YAG
Cont. Wave & Pulsed	Air	DPSS – Nd:YVO4	InGaAsP	Sr
Pulsed	Alexandrite	DPSS – Ruby	InGaN	Stilbene
Pulsed - Mode-Locking	AlGaAs	Dy:YAG	InP	Tb:YAG
Pulsed - Q-Switch	AlGalnP	Er:Codoped Glass	Iodine	Tetracene
Pulsed - Scanning	Aluminum Free DPSS	Er:Fiber	KrF Excimer	Ti:Sapphire
	Ar/Kr	Er:YAG	Krypton	Tm:Fiber
3 - Use	ArF Excimer	Er:YLF	Lead Salt	Tm:YAG
Educational	Argon	ErYb:Codoped Glass	Malachite Green	U:CaF2
Entertainment	Au	F-Center	Nd:Fiber	Umbelliferone
Industrial	Ce:LiCAF	Fluorescein	Nd:Glass	VCSEL
Industrial, Manufacturing	Ce:LiSAF	GaAs	Nd:YAG	XeCl Excimer
Industrial, Processing	Ce:YAG	GaN	Nd:YCOB	Xenon
Law Enforcement	Chrysoberyl	GaSb	Nd:YLF	Yb:Fiber
Medical	CO	HeAg	Nd:YVO4	Yb:Glass
Medical, Cosmetic	CO2	HeCd Gas	NdCe:YAG	Yb:YAG
Medical, Dental	COIL	HeCd metal vapor	NdCr:YAG	Yb2O3
Medical, Educational	Copper Vapor	HeHg	NeCu	
Medical, Eye	Coumarin	Helium	Nitrogen	
Optical Fiber Communications	Cr:YAG	HeNe	Oxygen	
Research & Development	Cr:ZnSe	HeSe	Pm147:Glass	
Veterinary	Cu	HF	Quantum Cascade	
Welding	DF	Ho:YAG	Rhodamine	
	Diode	HoCrTm:YAG	Ruby	
	Diode-Pumped Solid State (DPSS)	Hybrid Silicon	Sm:CaF2	

APPENDIX N

Wellesley College Policy for Post Exposure Laser Eye Exams

In the event that a laser worker/user suspects they have been exposed to excessive levels of laser radiation, act quickly and follow the below steps:

1. Notify Campus Police immediately at X5555.

2. Contact the appropriate facility for medical care, bring **Attachment 1**, below with you to the doctor:

For Employees:

Beth Israel Deaconess
Occupational Health Clinic
148 Chestnut Street
Needham, MA
(781) 453-3000

For Students:

Health Services
Simpson Infirmary
X2810

3. Contact the Laser Safety Officer to report the incident:

Dawn Too – Assistant Director of Environmental Health and Safety
Office location: Distribution Center
dt100@wellesley.edu
781-283-2762

4. Fill out a Laboratory Accidents Report found at www.wellesley.edu/safety/accidents Distribute the report according to the directions at the bottom. For all employee incidents, also fill out the appropriate Accident Report and Tracking form under the "For Employees" section at the above site, distribute according to the directions on the form.

The LSO and the Laser Supervisor will investigate any suspected exposure to excessive levels of laser radiation. A copy of the report will be maintained in the employee's medical file; student-related incident reports will be maintained by Health Services.

All near miss incidents, equipment malfunctions capable of producing injury and unauthorized use of lasers and laser systems must also be reported immediately to the LSO.

I. Scope

This policy applies to all individuals directly involved with use of lasers at Wellesley College.

II. Purpose

To establish the Wellesley College Policy for post-exposure or suspected exposure eye exams. These requirements reflect those stated in ANSI Z136.1-2014, Appendix E, Medical Surveillance.

III. Requirements

Incident-Related Eye Exams

In the event of any accidental or suspected eye exposure to laser radiation, a thorough eye examination shall be conducted as specified in Attachment 1. Records of these results shall be maintained in the individual's medical file.

Billing Procedures

Laser eye examinations shall be provided at no cost to the employee or student in the event of incidental laser exposure.

Attachment 1

*In the event of incidental eye exposure, bring this information to your doctor.

E2.2.1 Ocular History. The past eye history and family histories are reviewed. Any current complaints concerned with the eyes are noted. Inquiry should be made into the general health status with a special emphasis upon systematic diseases which might produce ocular problems in regard to the performance cited in Section 6.1 of ANSI Z136.1-2014. The current refraction prescription and the date of the most recent examination should be recorded. Certain medical conditions may cause the laser worker to be at an increased risk for chronic exposure. Use of photosensitizing medications, such as phenothiazines and psolarens, lower the threshold for biological effects in the skin, cornea, lens and retina of experimental animals exposed to ultraviolet and near ultraviolet radiation. Aphakic individuals would be subject to additional retinal exposure from blue light and near ultraviolet and ultraviolet radiation. Unless chronic viewing of these wavelengths is required, there should be no reason to deny employment to these individuals.

E2.2.2 Visual Acuity. Visual acuity for far and near vision should be measured with some standardized and reproducible method. Refraction corrections should be made if required for both distant and near test targets. If refractive corrections are not sufficient to change acuity to 20/20 (6/6) for distance, and Jaeger 1 + for near, a more extensive examination is indicated as defined in 6.3 of ANSI Z136.1-2014.

E2.2.3 Macular Function. An Amsler grid or similar pattern is used to test macular function for distortions and scotomas. The test should be administered in a fashion to minimize malingering and false negatives. If any distortions or missing portions of the grid pattern are present, the test is not normal.

E2.2.4 Color Vision. Color vision discrimination can be documented by Ishihara or similar color vision tests.

E2.2.5 Examination of the Ocular Fundus with an Ophthalmoscope. This portion of the examination is to be administered to individuals whose ocular functions described in E2.2.1 through E2.2.4 of ANSI Z136.1-2014 are not normal. Points to be covered are: the presence or absence of opacities in the media; the sharpness of outline of the optic disc; the color of the optic disc; the depth of the physiological cup, if present; the ratio of the size of the retinal veins to that of the retinal arteries; the presence or absence of a well-defined macular and the presence or absence of a foveal reflex; and any retinal pathology that can be seen with an ophthalmoscope (hyper-pigmentation, depigmentation, retinal degeneration, exudate, as well as any induced pathology associated with changes in macular function). Even small deviations from normal should be described and carefully localized. Dilation of the pupil is required.

APPENDIX O

Current laser-related contacts as of August 30, 2020

Laser Safety Officer

Dawn Toon – Assistant Director of Environmental Health and Safety
Office location: Distribution Center
dt100@wellesley.edu
781-283-2762

Laser Supervisors

Glenn Stark – Physics Professor
Office: S262
Lab: E215 Teaching Lab
gstark@wellesley.edu
781-283-3108

Robbie Berg – Physics Professor
Office: S256A
Lab: E115
rberg@wellesley.edu
781-283-3110

Lauri Wardell – Senior Lecturer in Physics
Office: S393
Lab: E215 Teaching Lab
lwardell@wellesley.edu
781-283-3324

James Battat – Assistant Professor of Physics
Office: S260
Lab: E222
jbattat@wellesley.edu
781-283-3142

Jerome Fung – Lecturer in Physics
Office: E214
Lab: E215 Teaching Lab
jfung2@wellesley.edu
781-283-3193

Amy Banzaert – Director of Engineering Studies

Office: L001
Lab: L024 (Engineering)
abanzaer@wellesley.edu
781-283-3756

Larry Knowles – Machinist – assists with Engineering laser engraver/cutter
Office: L023
Lab: L024 (Engineering)
lknowles@wellesley.edu
781-283-3126

Geraldine Echebiri – Instructor in Chemistry Laboratory
Office: S271
Lab: L218, E115
gechebir@wellesley.edu
781-283-3365

APPENDIX P

The Laser Safety Program at Wellesley College follows ANSI Z136.1, Z136.5 and Z136.8 – related to "The Safe Use of Lasers" and the MA DPH Regulations. Copies of the written program, ANSI Standards and the MA DPH Regulations are available through the Laser Safety Officer.

ANSI Standards:

ANSI Z136.1 – Safe Use of Lasers

ANSI Z136.5 – Safe Use of Lasers in Educational Institutions

ANSI Z136.8 – Safe Use of Lasers in Research, Development, or Testing

The Massachusetts Department of Public Health (MDPH) Bureau of Environmental Health's (BEH) Radiation Control Program (RCP) protects the health and safety of the residents of the Commonwealth from the harmful effects of ionizing and non-ionizing radiation. Lasers are a form of non-ionizing radiation. 105 CMR 121.000 regulates lasers in Massachusetts.

105 CMR 121.000: TO CONTROL THE RADIATION HAZARDS OF LASERS, LASER SYSTEMS AND OPTICAL FIBER COMMUNICATION SYSTEMS UTILIZING LASER DIODE OR LIGHT EMITTING DIODE SOURCES