WILLIAMS COLLEGE
LASER SAFETY PROGRAM

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WILLIAMS COLLEGE

LASER SAFETY PROGRAM

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 is emitted over a wide range of the electromagnetic spectrum from the ultraviolet region through the visible to the infrared region. The range of the commonly available laser is from 200 nanometers to 10.4 micrometers. Laser radiation may be emitted as a continuous wave or in pulses.

Lasers produce primarily non-ionizing radiation. The most frequent mechanism of beam damage for 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, and the responsibilities of the laser user community in ensuring the safe use of laser radiation.

Overall responsibility for compliance with legislative regulations and industry standards for safe use of both ionizing or non-ionizing radiation is assigned to the Williams College Radiation Safety Committee. This committee reports to the Provost's Office. Laser safety regulations have been promulgated by the Massachusetts Public Health Department (MPHD) under the provisions of Section 51, Chapter 111 of The General Laws of Massachusetts. Additional guidance in preparing this manual has been derived from ANSI Standard Z136.1-1980.

II. 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 eye wear, 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 the 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. Avoid wearing rings or other metallic objects. Know where the main power shutoff is located.

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 are 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 x-radiation from high voltage power supplies.

III. Hazard Controls

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

a) the laser system classification

b) the environment where the laser system is used

c) the laser system operating characteristics

d) the persons operating the laser system

e) the general population within the vicinity of the laser system

Laser safety procedures can best be evaluated by grouping them according to the class of laser system in use. Appendix D of this program provides a list of appropriate control measures for each laser system classification. Any exceptions to these control measures require approval from the Laser Safety Subcommittee.

IV. RESPONSIBILITIES

A. Laser Safety Subcommittee

The Laser Safety Subcommittee (LSS), comprised of all Authorized Laser Researchers, is a subcommittee of the Radiation Safety Committee (RSC). The LSS is charged with ensuring the safe use of all laser systems on campus. Responsibilities of this committee include:

1. Establishing policies on the safe use of laser systems.
2. Reviewing the radiation safety aspects of the use of all laser systems on campus.
3. Reviewing applications of Authorized Laser Users before they are brought to the full committee for approval.
4. Reviewing reports of accidents and incidents involving the use of laser systems and assuring that appropriate corrective action is taken to prevent reoccurrence.

B. Laser Safety Officer

The Laser Safety Officer (LSO) will perform, as an integral part of the overall Williams College radiation safety program, the actions required to establish and maintain preventive measures to safeguard personnel from harmful effects of laser radiation. Responsibilities of the LSO include:

1. Reviewing laser facility use procedures to assure safe use.
2. Maintaining a current laser inventory to comply with the MPHD registration requirement.
3. Performing laser safety surveys of all Class 3B and Class 4 laser systems on campus at least yearly (Class 1, 2 and 3A laser systems will not be surveyed on a regular basis). See Appendix C for list of items covered during a laser safety inspection.
4. Maintaining all required records for MPDH inspection.
5. Investigating all accidents of incidents involving laser radiation to determine the cause(s) and to recommend corrective action to the LSS.
6. Providing the LSS and individual users with advice and assistance on all matters pertaining to the safe use of laser systems.
7. Serve as the chair of the LSS.

The LSO may designate a qualified replacement to perform any of the above tasks.

C. Authorized Laser Researchers

Researchers using laser systems are responsible to the LSS for ensuring their safe use. Each faculty member wishing to use or supervise the use of laser systems in research must submit an "Application for Authorization to Use Lasers at Williams College". The application (Appendix A) must include details of the faculty member's training and experience, and a description of the procedures to be performed, including all relevant safety precautions. This will be renewed annually. Specific responsibilities include:

1. Complying with and enforcing the safety requirements prescribed in this manual.

2. Providing laser system safety training to all personnel requiring training prior to use and filing documentation of this training with the RSC. Possible training videos will be kept in Dr. Skinner's office.
3. Where applicable, arranging eye examinations for any individual users in the group.
4. Ensuring that all required protective equipment is used during laser work.
5. Reviewing in advance all lab procedures to be used by personnel under their supervision in carrying out research work involving laser radiation, for probability of overexposure, explosion, implosion, fire or other hazards.
6. Ensuring the integrity of associated equipment such as vacuum systems, cryogenic systems, pressure vessels or other similar equipment.
7. Ensuring that all laser system safety interlocks, warning lights, etc., are functioning.
8. Posting warning signs and otherwise controlling laser hazards in the areas for which s/he is responsible.

D. The Individual Laser User

Individual users work under the supervision of Authorized Researchers. They include research students and technical staff, but not students in regularly scheduled courses. The individual user is responsible for:

1. Wearing prescribed protective glasses and any other protective clothing or equipment.
2. Using only authorized techniques and procedures.
3. Complying with all sections of this manual.

E. Use of Laser Systems in Regularly Scheduled Courses

Anyone wishing to use a Class 4 laser system, a Class 3 laser system with beam invisible to the eye or a CW Class 3B laser system with beam power >15 mW must submit an application to the RSC through the LSS. This includes those faculty planning lab experiments or demonstrations as part of course work. The applicant will become an Authorized User for this purpose only. Such Authorized Users will not be expected to attend all LSS/RSC meetings, but will receive copies of agendas and minutes. Approval is subject to the same annual renewal review as any other Authorized User application. If in subsequent years another faculty member becomes responsible for this experiment or demonstration, the new faculty member must file their own application. At the September RSC meeting, a departmental representative from any department using these systems will be asked to poll the department and report back on any new uses that require committee attention.

V. Laser Registration

In acordance with regulations of the Massachusetts Department of Public Health, all laser systems should be registered, using the form available from the LSO. Class 4 laser systems, Class 3 laser systems which produce a beam invisible to the eye, and Class 3B systems with output power >15 mW are of particular concern. These shall be registered with the LSO, using the form shown as Appendix B.

VI. Laser Classifications

Each laser system shall be classified according to the definitions of Section 3.3 of ANSIZ136.1 (see Appendix D). In addition to meeting the general requirements of Section 3.5.1 of this HSD, laser systems must meet specific requirements based on laser system class. Laser classifications and entry controls are summarized below along with a summary of essential requirements. As of September 19, 1985, certified laser system manufacturers must label their products as to class.

Class 1 denotes exempt laser systems that cannot, under normal operating conditions, produce a hazard.

Equipment such as laser printers that completely enclose the laser system and laser beam are normally specified as Class 1.

Class 2 denotes low power visible-radiation laser systems. Visible cw HeNe laser systems above Class 1, but not exceeding 1 mW radiant power, are common examples of this class. Because of the normal human aversion responses, these laser systems normally do not present a hazard, but may present some potential for hazard if viewed directly for extended periods of time (like many conventional light sources).

Many laser pointers are Class 2, although there are also Class 3 pointers.

Class 3A denotes visible-radiation laser systems that normally would not produce a hazard if viewed for only momentary periods with the unaided eye. They may present a hazard if viewed using collecting optics. Visible cw HeNe laser systems above 1 milliwatt (mW), but not exceeding 5 mW radiant power, are common examples of this class.

Class 3B denotes laser systems that can produce a hazard if viewed directly. This includes intrabeam viewing or specular reflections. Except for the high power Class 3B laser systems, this class laser system will not produce hazardous diffuse reflections. Visible cw HeNe laser systems above 5 mW, but not exceeding 500 mW radiant power, are examples of this class as are all laser systems with beams invisible to the eye and a power >1 mW.

Class 4 denotes laser systems that can produce a hazard not only from direct or specular reflections, but also from a diffuse reflection. In addition, such laser systems may produce fire and skin hazards. Argon ion, Nd:YAG, CO_2, N_2, and excimer laser systems are some examples of lasers that may be classified as Class 4 laser systems.

The existence of **homemade laser systems** shall be made known to the LSO so that a proper hazard classification based on ANSI standards can be made on the laser system.

VII. Laser Safety Controls

The safety rules accompanying laser classifications can be summarized as follows:

A. Class 1 Controls

No user safety rules are necessary.

B. Class 2 Controls

1. Never permit a person to stare continuously into the laser source.

2. Never point the laser system at an individual's eye unless a useful purpose exists and the exposure level and duration will not exceed the permissible limit.

C. Class 3A Controls

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

2. Always use proper laser eye protection if a potential eye hazard exists from the direct beam or a specular reflection. Before energizing a laser system, verify that prescribed safety devices for the unit are being properly employed. These may include opaque shielding, nonreflecting and/or fire-resistant surfaces, goggles and/or face shields, door interlocks, and ventilation for toxic material.

3. Do not aim the laser system at an individual's eye.

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

5. Enclose as much of the beam path as practicable. Even a transparent enclosure will prevent individuals from placing their head or reflecting objects within the beam path. Terminations should be used at the end of the useful paths of the direct beam and any secondary beams.

6. "High Voltage" signs should be put on removable power supply panels to reduce the chance of electrical accident.

7. Place the laser beam path well above or well below the eye level of any sitting or standing observers whenever practicable.

8. The beam or its specular reflection should never be directly viewed with optical instruments such as binoculars or telescopes without sufficient protective filters.

9. Remove all unnecessary mirror-like surfaces from the vicinity of the laser beam path. Do not use reflective objects such as credit cards to check beam alignment. Remove any jewelry to avoid inadvertent reflections.

NOTE: The reflectivity of an object is a function of the wavelength of the laser beam.

10. Be alert to the danger of excessive noise, which may prevent users or spectators from recognizing that the laser system is in operation.

11. Do not permit laser tracking of vehicles.

12. Teaching or research labs using Class 3A laser systems should have a sign on the door reading "CAUTION - Laser in Use.

D. Class 3B Controls

1. All Class 3A controls apply to Class 3B.

2. A key switch should be installed to avoid tampering by unauthorized individuals.

3. A warning light or buzzer on the laser system should indicate laser operation. This is especially needed if the beam is not visible, i.e., for infrared laser systems.

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

5. Control the access to the laser facility. This can be done by clearly designating those who have access to the laser room. Implement access control by installing warning signs on the outside door. Control spectators, such as non-research students, to avoid unsafe exposures.

6. Class 3B laser systems with output >15 mW should be operated only in a restricted area--for example, in a closed room without windows. Place a sign on the door reading “Danger”. CW Class 3B laser systems with beam power <15 mW are not considered to present the same level of hazard (see Appendix F).

7. Avoid leaving a Class B laser system with output power >15 mW unattended when it is in operation. If a laser system is to be unattended on a regular basis for more than the warm-up period, this should be noted in the Authorized Laser Research application. It will be expected that the room containing this laser system will be kept locked.

E. Class 4 Controls

1. All controls listed for Class 3 laser systems also apply to Class 4 laser systems.

2. These laser systems should only be operated within a localized enclosure, or in a controlled workplace. If a complete local enclosure is not practicable, indoor laser operation should be in a light-tight room with interlocked entrances to assure adequate warning to anyone desiring access that the laser system is turned on.

3. Appropriate eye protection is required for all individuals working within the controlled area.

4. If the laser beam irradiance is sufficient to be a serious skin or fire hazard, a suitable shielding should be used between the laser beam and any personnel or flammable surfaces.

5. The flashlamps in optical pump systems should be shielded to eliminate any direct viewing.

6. Backstops should be diffusely reflecting, fire resistant target materials where practicable.

7. Walls and ceiling 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.

IX. MEDICAL SURVEILLANCE

All authorized laser system users using Class 4 laser systems, Class 3B laser systems which produce beams invisible to the eye, and CW Class 3B laser systems that produce visible beams with greater than 15 mW power, their research students, and any support staff regularly employed in such work must have eye examinations as detailed in Appendix F before starting work. They will normally also have eye examinations at the end of their College laser system usage. All examinations will be at College expense.

In the event that a laser worker suspects s/he has been exposed to excessive levels of laser radiation, the following steps should be taken:

1. Notify the Laser Safety Officer immediately.

2. Report to the Health Center for referral to an opthamologist for an eye exam, or to a physician for skin injury.

3. File a laser incident report with LSO.

The LSO will investigate any suspected exposure to excessive levels of laser radiation and file a report to the Laser Safety Subcommittee. A copy of the report will be maintained in the laser workers' registration file.

APPENDIX A

WILLIAMS COLLEGE

AUTHORIZED LASER RESEARCHER APPLICATION

SECTION I: INFORMATION Date: _____

1. Name: _____
(Print) Last First M.I.

2. Social Security Number:_____ Title:_____

3. Department _____

4. Office:_____ Ext.:_____

5. Laboratory _____ Ext.:_____

6. Description of laser and work involving lasers:

LASER Type:_____ Classification: _____

Description (include safety precautions):

_____

_____

_____

(If more space is needed, attach extra page.)

SECTION II: PREVIOUS EXPERIENCE WITH LASER(S)

1. Previous experience with laser(s):

   Laser Type:_____ Classification:_____

   Description:
_____

2. Have you had any exposures to laser radiation in amounts known (or suspected) to be above the ANSI Z136.1-1986 maximum permissible exposure?

   Yes: _____ No: _____ Unknown: _____

3. I have received and read the Laser Safety Handbook regarding the use of lasers at Williams College. I agree to comply with all applicable rules and regulations governing the safe use of lasers at Williams College.

   Signature:_____ Date:_____

SECTION III: APPROVAL

1. Application Approved ____ Disapproved _____ Date:_____

2. Medical Surveillance Recommended:

   (a) Eye Examination: _____ (b) Other:_____

3. Comments:

SECTION IV: TERMINATION (to be completed by LSO)

1. Date:_____

2. Medical Surveillance Recommended:

   (a) Eye Examination: _____ (b) Other:
_____

3. Comments:

Signed: _____

APPENDIX B

WILLIAMS COLLEGE
APPLICATION FOR REGISTRATION OF LASER SYSTEMS

Complete Section I and forward to the Laser Safety Officer (LSO).

Section I

A. Identification of person or department who will supervise use of Laser equipment:

Name_____ Department _____ Tel. No. _____

B. Location of laser system: Room _____

C. General conditions relating to the application:

1. The supervisor is responsible for ensuring that the laser system is used in the manner specified by the Laser Safety Program. There shall be no changes in approved procedures without the prior approval of the Laser Safety Subcommittee. LSO shall be notified prior to a change in place of use of the equipment.
2. Routine operation of this equipment may not begin until LSO has been notified and has conducted a thorough survey and given approval for operation. Additional surveys will be made by RPO at intervals not to exceed 12 months.
3. All personnel shall be appropriately trained by the supervisor before working with this equipment.

Supervisor's Signature _____ Date: _____

Supervisor's Name (Print):_____

D. Laser Information

Laser System Serial/ID # _____ Safety Class _____ Laser Media _____

Wavelength(s)_____ Power/Energy _____ Mode of Operation _____

Location _____ Purpose of Use _____

Notes: Laser Media - indicate media utilized, i.e., HeNe, CO_2, Yag, Ruby, Glass, Liquid (type), Argon.
Power/Energy Level - output power in watts. Output energy in Joules per pulse.
Mode of Operation - indicate all modes in which the system is used. [CW (continuous wave), NP (normal pulse, millisecond range), PRF (pulse repetition rate), Q-S (Q-Switched, microseconds)]
Safety Classification - Class 1, 2, 3a, 3b, or 4 as indicated by manufacturer.

Section II This section is to be completed by the Laser Safety Officer.

A. Hazard Control Recommendations:

B. Date(s) of Laser Inspections:

C. Additional comments:

D. LSO Signature _____ Date: _____

APPENDIX C

LASER RADIATION SURVEY

I. GENERAL INFORMATION

A. Location

Survey Date/Time:_____ Bld. and Room Number: _____

Registration #: _____ Telephone Number:_____

Project Supervisor: _____

Person(s) Interviewed: _____

B. Laser System

Type of Laser(s): _____

Serial Number(s): _____

Power(s): _____

II. RADIATION PROTECTION CHECKLIST

A. Signs/Labels: _____

B. Shielding: _____

C. Control of Room Access: _____

D. Warning Device when Energized: _____

E. Interlock System: _____

F. Eye Protection Available and in Good Condition: _____

G. Room Illumination: _____

H. Reflective Surfaces in Room: _____

I. Elements in Beam Path Secured: _____

J. Date of Last Inspection: _____

K. Personnel Registered with LSS: _____

L. Other: _____

_____

Signature: _____ Date:_____

APPENDIX D

CONTROL MEASURES FOR THE FOUR LASER CLASSES
AMERICAN NATIONAL STANDARD Z136.1-1986

Controls	Classification	1	2a	2	3a	3b	4
ENGINEERING	Protective Housing (4.3.1)	X	X	X	X	X	X
	Without Protective Housing (4.3.1.1)	LSO shall establish Alternate Controls					
	Interlocks on Protective Housing (4.3.2)	A	A	A	X	X	X
	Service Access Panel (4.3.3)	V	V	V	V	V	X
	Key Switch Master (4.3.4)	—	—	—	—	•	X
	Viewing Portals (4.3.5.1)	—	—	O	O	O	O
	Collecting Optics (4.3.5.2)	—	—	O	O	O	O
	Totally Open Beam Path (4.3.6.1)	—	—	—	—	X	X
	Limited Open Beam Path (4.3.6.2)	—	—	—	—	X	X
	Remote Interlock Connector (4.3.7)	—	—	—	—	•	X
	Beam Stop or Attenuator (4.3.8)	—	—	—	•	•	X
	Activation Warning Systems (4.3.9)	—	—	—	—	•	X
	Emission Delay (4.3.9.1)	—	—	—	—	—	—
	Class 3b Laser Controlled Area (4.3.10.1)	—	—	—	—	X	—
	Class 4 Laser Controlled Area (4.3.10.2)	—	—	—	—	—	X
	Laser Outdoor Controls (4.3.1 1)	—	—	—	—	X	X
	Temporary Laser Controlled Area* (4.3.12)	V	V	V	V	—	—
	Remote Firing & Monitoring (4.3.13)	—	—	—	—	—	-
	Labels (4.3.14)	—	X	X	X	X	X
	Area Posting (4.3.15)	—	—	•	•	X	X
ADMINISTRATIVE & PROCEDURAL	Administrative & Procedural Controls (4.4)	—	X	X	X	X	X
	Standard Operating Procedures (4.4.1)	—	—	—	—	•	X
	Output Emission Limitations (4.4.2)	—	—	—	LSO Determination		
	Education and Training (4.4.3)	—	—	•	X	X	X
	Authorized Personnel (4.4.4)	—	—	—	—	X	X
	Alignment Procedures (4.4.5)	—	—	X	X	X	X
	Eye Protection (4.4.6)	—	—	—	—	•	X
	Spectator Control (4.4,7)	—	—	—	—	•	X
	Service Personnel (4.4.8)	V	V	V	V	X	X
	Laser Demonstration (4.5.1)	—	—	X	X	X	X
	Laser Fiber Optics (4.5.2)	—	—	X	X	X	X

LEGEND
X Shall
• Should
— No requirement
V Shall if embedded Class 3b or Class 4
O Shall if MPE is exceeded
A Shall if embedded Class 3a, Class 3b, Class 4
* During service only

Table 1

Accessible Emission Limits for Selected Continuous-Wave* Lasers and Laser Systems

Wavelength Range (μm)	Emission Duration (s)	Class 1 †	Class 2‡	Class 3§	Class 4
Ultraviolet 0.2 to 0.4	3×10^4	≤0.8×10^{-9}W to ≤8×10^{-6} W depending on wavelength (see Table 5)	—	>Class 1 but 50.5 W depending on wave-length (sec Table 5)	> 0.5 W
Visible 0.4 to 0.7	3×10^4	≤$0.4\ C_B \times 10^{-6}$ W**	> Class 1 but ≤1×10^{-3} W	>Class 2 but ≤ 0.5 W	>0.5 W
Near Infrared 0.7 to 1.06	3×10^4	≤0.4×10^{-6} W to ≤ 200×10^{-6} W depending on wavelength (see Fig. 9)	—	>Class 1 but 50.5 W depending on wave.	> 0.5 W
Near Infrared 1.06 to 1.4	3×10^4	≤ 200×10^{-6} W	—	> Class 1 but ≤ 0.5 W	> 0.5 W
Far Infrared 1.4 to 10^2	> 10	≤ 0.8×10^{-3} W	—	>Class 1 but ≤ 0.5 W	> 0.5 W
Submillimeter 10^2 to 10^3	>10	≤ 0.1 W	—	>Class 1 but ≤0.5W	> 0.5 W

* Emission duration ≥ 0.25 s.

** For C_B see Notes to Tables 5 and 6.

† When the design or intended use of the laser or laser system ensures personnel exposures of less than 10^4s in any 24-hour period, the limiting exposure duration may establish a higher exempt power level, as discussed in 3.2.3.

‡ See 3.3.2.2 for explanation of Class 2a laser.

§ For I to 5 mW cw laser systems (Class 3a) see 3.3.3.1 and 3.3.3.2.

Table 2

Summary of Levels (Energy and Radiant Exposure Emissions)

for Single-Pulsed Laser and Laser System Classification*

Wavelength Range (μm)	Emission Duration** (s)	Class 1	Class 3	Class 4
Ultraviolet † 0.2 to 0.4	> 10^{-2}	≤ 24 x 10^{-6} 1 to 7.9 x 10^{-3} J	>Class 1 but ≤ 10 J • cm^{-2}	> 10 J • cm^{-2}
Visible 0.4 to 0.7	10^{-9} to 0.25	≤ 0.2 x 10^{-6} J	> Class 1I but ≤ 31 x 10^{-3} J • cm^{-2}	> 31 x 10^{-3} J • cm^{-2}
		≤ 0.25 x $I0^{-3}$ J	> Class 1 but ≤ 10 J • cm^{-2}	> 10J • cm^{-2}
Near Infrared ‡ 0.7 to 1.06	10^{-9} to 0.25	≤ 0.2 x 10^{-6} to 2 x 10^{-6} J	> Class 1 but ≤ 31 x 10^{-3} J • cm^{-2}	> 31 x 10^{-3} J • cm^{-2}
		≤ 0.25 x 10^{-3} to 1.25 x 10^{-3} J	> Class 1 but ≤ 10 J • cm^{-2}	> 10 J • cm^{-2}
1.06 to 1.4	10^{-9} to 0.25	≤ 2 x 10^{-6} J	> Class 1 but ≤ 31 x 10^{-3} J • cm^{-2}	> 31 x 10^{-3} J • cm^{-2}
		≤1.25 x 10^{-3} J	> Class 1 but ≤ 10 J • cm^{-2}	> 10 J • cm^{-2}
Far Infrared 1.4 to 10^2	10^{-9} to 0.25	≤ 80 x 10^{-6} J	> Class 1 but ≤ 10 J • cm^{-2}	> 10 J • cm^{-2}
		≤ 3.2 x 10^{-3} J	> Class 1 but ≤ 10 J • cm^{-2}	> 10 J • cm^{-2}
Submillimeter 10^2 to 10^3	10^{-9} to 0.25	≤ 10 x 10^{-3} J	> Class 1 but ≤ 10 J • cm^{-2}	> 10 J • cm^{-2}
		≤ 0.4 J	> Class 1 but ≤ 10 J • cm^{-2}	> 10 J • cm^{-2}

* There are no Class 2 single-pulsed lasers.

** See Note in Section 8 for pulse widths less than I ns,

† Wavelength dependent (see Table 5).

‡ Diffuse reflection criteria (Table 3) apply from 10^{-9} to 33 x 10^{-3} s for Class 3. For > 33 x 10^{-3} s exposure, the maximum radiant exposure is 10 J • cm^{-2}. Class 1 and 3 values are wavelength dependent (see Fig. 8).

APPENDIX F

LASERS IN CLASSROOMS AND TEACHING LABORATORIES

Class 3b as described in ANSI Z136.1 includes a number of laser system types commonly used in classroom demonstrations and laboratory work. Most notably, it includes small HeNe systems which have an output of <15 mW. These systems, under conditions of classroom or laboratory usage at Williams College, do not pose a threat greater than that of Class 3A systems. By proper education and especially supervision of students, and the use of beam expanding and attenuating optics in clearly defined protocols, exposure can be kept below the MPE. It is not, therefore, necessary to restrict access to the rooms in which such laser systems are used, nor to require that the room have no windows. Use of a "Caution" sign is also more appropriate than one reading "Danger".

APPENDIX G

LASER EYE EXAMINATION PROTOCOL

OCULAR HISTORY

The patient's past eye history and family eye history shall be reviewed. Any current eye complaints which an employee has shall be noted. The patient's general health status should be determined with a special emphasis upon diseases which can give ocular problems. The employee's present lens prescription, if any, shall be recorded.

VISUAL ACUITY

Distance visual acuity shall be tested and recorded in Snellen figures for 20 feet with an without lenses, if any. Reading visual acuity shall be tested at 35 cm and recorded in Jaeger test figures with and without lenses, if any.

EXTERNAL OCULAR EXAMINATION

This includes examination of brows, lids, lashes, conjuctiva, sclera, cornea, iris and pupillary size, and equality, reactivity, and regularity.

MANIFEST REFRACTION

This is to measure the employee's refractive error and the new visual acuity of the employee shall be noted if the visual acuity is improved over that achieved with the employee's old lens prescription, or if he has no lenses at the time of the examination. This examination shall be carried out on all personnel whose visual acuity in either eye is less than 20/20.

MEASUREMENT OF INTRAOCULAR PRESSURE

Intraocular pressure should be measured before the pupils are dilated. The employee's pupils are then dilated by the instillation of a mydriatic drop in each eye. The remainder of the examination is carried out with the eye under this medication.

EXAMINATION BY SLIT LAMP

The cornea, iris, and lens are examined with a biomicroscope and described.

EXAMINATION OF THE OCULAR FUNDUS WITH AN OPHTHALMOSCOPE

In the recording of this portion of the examination, the points to be covered are: the presence or absence of opacities in the media; the sharpness of outline of the optic nerve; the color of the optic nerve; the size of the physiological cup, if present; the presence or absence of a well-defined macula and the presence or absence of a foveolar reflex, and any retinal pathology that can be seen with a direct ophthalmoscope. Even small deviations from normal should be described and carefully localized.

OTHER EXAMINATIONS

Further examinations are to be done as deemed necessary by the examiner.

APPENDIX H

EYE PROTECTION AND MAXIMUM PERMISSIBLE EXPOSURES

Laser irradiation of the eye may cause damage to the cornea, the lens, or the retina, depending o the wavelength of the light and the energy absorption characteristics of the ocular media (see Fig. 1). Lasers 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--Visible and Near Infrared (Spectral Region 400-1400nm)

Visible wavelengths penetrate through the cornea to be focused on a small area of the retina, the fovea centralis. 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--Infrared (Spectral Region 1.4 to 1000mm)

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

3. Corneal Damage--Ultraviolet (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. 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 to 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 regional, 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.

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). The M.P.E. values for visible light are based on a pupil diameter of 7mm, which is considered to be 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. MPE's for intrabeam viewing and diffuse reflections are given in Tables 3 and 4.

6. PROTECTIVE EYE WEAR

ANSI Z136.1 requires that protective eye wear 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 eye wear that attenuates the intensity of laser light while transmitting enough ambient light for safe visibility (luminous transmission). The ideal eye wear 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 eye wear, careful consideration must be given to the operating parameters, M.P.E.s, and wavelength. Appropriate eye wear information may be acquired for a particular laser from the manufacturer at the time of purchase.

NOTE: Persons working with lasers emitting in the visible region are often unwilling to wear protective eye wear 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.

APPENDIX I

DEFINITIONS

The definitions of the terms listed below are 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 with 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 1/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 or greater 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.

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 a 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 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 Appendices J, K and L.

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 by Stimulated 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.

optical density - Logarithm to the base ten of the radiant exposure (J/cm^2) or of the irradiance (W/cm^2) divided by the corresponding 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.

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; 2p radians = 360 degrees.

radiance (L) - Radiant flux or power output per unit solid angle per unit area. Unit: Watts per centimeter squared per Steradian ($W/cm^2/sr^1$).

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 powe*r.

shall - "Shall" means the ensuing recommendation is necessary or essential to meet currently accepted safety standards.

should - "Should" means advisory recommendations that are to be applied wherever practicable.

specular reflection - a mirror-like reflection.