College Of Science and Mathematics

Laser Safety Manual

Adapted with Permission from Dr. Norm Van Houten of NJIT

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Section 1: Introduction

Introduction

A. Program Intent

The Montclair State University Laser Safety Program is intended to provide staff, researchers, students and visitors with a safe laser use environment. The manual was written to provide MSU laser safety policy and guidance on maintaining and documenting the program. The manual also serves as a reference source for laser users.

B. Regulatory Requirements

Regulation of laser hazards falls under Federal OSHA and NJ PEOSHA under ANSI Z136.1 Standard for the Safe Use of Lasers as the accepted "...safe and healthy work practice..." to use in inspecting laser facilities.

C. ANSI Z136.1 Standard for the Safe Use of Lasers

The MSU Laser Safety Program is based on the ANSI Z136.1 Standard for the Safe Use of Lasers. Copies of the standard are available from the Office of Environmental Health & Safety

D. MSU Laser Safety Program Overview

The MSU laser safety program covers primarily Class 3a, 3b and 4 lasers and laser systems on the campus (see Section 2). The program is divided into seven basic areas.

Section 2: Laser Safety Program

L. Laser Incidents

Laser Safety Program

A. Responsibilities and Program Administration

Laser Safety Committee

If warranted by the magnitude of the potential hazards of laser operation within the organization, a Laser Safety Committee may be formed.

Department Chairperson

Department chairpersons are responsible for assuring their PIs (principal investigators) who use lasers operate those lasers safely and implement the Laser Safety Program.

Principal Investigator

PIs are directly responsible for implementing the Laser Safety Program. This includes the implementation of specified hazard controls, oversight and management of non-laser hazards, and
informing the EH&S or it's designee of any changes that affect the laser users. It is also the responsibility of the PI to assure that all laser users operating under his or her LUR have met the training requirements set forth by EH&S.

Laser User

Laser users are responsible for their own safety in the laser facility. All users must meet the laser safety-training requirement within 30 days of joining the LUR (using the laser). All laser users are responsible for following the LUR specific hazard controls and notification requirements.

B. Scope of the Program

The MSU Laser Safety Program primarily addresses Class 3a, 3b and 4 lasers. These lasers classes are operated under Laser Use Registrations (LURs) that describe the laser; it's use, hazard class, and the required laser safety measures. A LUR file is maintained by the Office of Environmental Health & Safety.

C. Acquisition, Modification, Sale or Transfer of Lasers

The campus LSO must be informed of the acquisition, modification, sale, or transfer of any Class 3a, 3b or 4 laser. The campus purchasing department supplies EH&S with copies of laser purchase order documents, However, it is the responsibility of the PI to inform EH&S or it's designee whenever acquisition, modification, sale, or transfer of a laser or laser system occurs.

D. The Laser Use Registration (LUR)

The LUR is initiated by the PI completing a LUR form (see Appendix C). The completed form is sent to EH&S or it's designee who contacts the PI to discuss the laser system and application. Modification of a LUR is usually done at the request of the PI. Under special circumstances, EH&S or it's designee may modify a LUR. Termination of a LUR is usually done at the request of the PI. Under special circumstances, EH&S or it's designee may choose to terminate a LUR. The LUR may be suspended by order of EH&S or it's designee if they feel that the health or safety of staff is in immediate danger. Documentation of all changes to a LUR are maintained by EH&S or it's designee.

E. Laser Safety Training

All laser users must read the Laser Safety Manual, the Laser Safety Training Supplement, and their specific LUR and certify in writing that they have done so. The training certification document can be found in the Laser Safety Training Supplement. EH&S is responsible for maintaining a file of the training certificates. Formal laser safety training presentations are available from the EH&S upon request. EH&S or it's designee may direct a PI to obtain a formal laser safety training presentation for his/her users. EH&S maintains documentation on all formal training presentations. The PI shall also provide and document that all laser users operating under his/her LUR have received specific hands-on instruction in use of the laser system, safety precautions associated with the laser, any standard operating procedures (SOPs) relating to the laser, and proper use of laser protective eyewear.

F. Laser Safety Inspections

Periodically, all laser facilities are inspected by EH&S or its designee to assure that the lasers are being operated in a safe manner. Copies of the inspection reports are provided to the PI for his/her review. EH&S maintains records of all inspections performed. The PI is responsible to correct unsafe conditions in a timely manner. EH&S or its designee will re-inspect the laser facility within 30 days to verify the correction of unsafe conditions. If a PI is unable to correct unsafe conditions in a timely manner, he/she may be asked to brief EH&S on the situation.

G. Eye Examinations

EH&S establishes criteria for eye examinations (found in Appendix D. Laser eye exams are required for all Class 3b and 4 laser users within 60 days of first joining the LUR. Additionally, laser eye exams will be performed after any suspected eye injury.

H. Personal Protective Equipment

The PI shall provide his/her laser users with the appropriate laser protective eyewear (refer to Appendix B for eyewear selection). Laser protective eyewear must be used for beam alignments if the viewed beam exceeds the ANSI Z136.1 MPE (maximum permissible exposure) value. Intra-beam viewing of lasers are not allowed on the MSU campus. Exemptions from these policies may be only granted by EH&S or its designee. Some ultraviolet (UV) laser uses may require the use of skin protection. Any need for skin protection will be identified by EH&S or its designee and communicated to the PI.

I. Beam Management

Laser beams must be restricted to the immediate location of use. Beams should be enclosed whenever practical. Beam blocks must be used to terminate beams. The use of shutters, collimators, curtains, and other beam control devices are strongly encouraged. It is the responsibility of the PI to verify through survey that appropriate beam management is being practiced.

J. Posting and Labeling

All access points to the laser facility must be marked with the ANSI standard laser hazard signs. Laser enclosures must be labeled to alert users to laser hazards as per the ANSI standard. Labels, laser hazard signs, and advice on their use are available from EH&S. Refer to Appendix D for the approved ANSI laser warning sign.

K. Access Control

Whenever the laser is in operation, access to laser facilities is restricted to laser users or persons being escorted by laser users. Access control must be maintained by positive means such as locked or interlocked doors. Laser warning signs alone are not considered sufficient to control access.

L. Laser Incidents

EH&S or its designee and PI must be informed immediately of any suspected laser incidents. See Appendix E for emergency procedures and emergency contacts. EH&S or its designee is responsible for investigating laser incidents, providing a report to the PI, and maintaining records on incidents.

Section 3: Laser Hazard Classification

Laser Hazard Classification

A. Determining Hazard Class Through Radiometric Parameters
The hazard class of the laser is extremely important in determining the appropriate hazard controls to make the laser system safe. EH&S or its designee assures that all MSU lasers are properly designated as to their appropriate hazard class. All commercially manufactured

lasers come marked with the hazard class as required under the FDA Center for Devices and Radiological Health (CDRH) regulations. Lasers made or modified at MSU will need to be evaluated by EH&S or its designee and appropriately classed. It is the responsibility of the PI to assist EH&S by supplying the appropriate radiometric parameters of the laser system. EH&S uses the ANSI Z136.1 standard to determine the appropriate hazard class.

B. Class 1 (Eye Safe Lasers)

Class 1 lasers are lasers that cannot cause injury from viewing the accessible laser radiation for the maximum possible duration inherent in the design. Very few lasers are Class 1, however, many laser systems can be made into Class 1 systems by totally enclosing the laser beam and interlocking the enclosure. Class 1 lasers do not require a LUR.

C. Class 2a and 2 (Safe Through the Aversion Response)

Class 2a lasers are defined as visible lasers that are not intended to be viewed and do not exceed the Class 1 AEL (accessible emission limit) for an exposure duration less than or equal to 1000 seconds. Class 2a lasers are often used in grocery scanner systems. Class 2 lasers are defined as visible lasers that will not cause injury to the eye when viewed for 0.25 seconds or less. The human aversion response (blinking or turning away from the beam) is triggered by the bright glare of the visible beam entering the eye, and is estimated to occur in about 0.25 second. Eye injury can occur if collecting optics are used in viewing the beam or if an individual overrides the aversion response and continues to stare into the beam path. As with all lasers, DO NOT LOOK INTO THE BEAM. Class 2 lasers may not exceed a output power of 1 mW. Class 2a and 2 lasers do not require a LUR.

D. Class 3a and 3b (Intrabeam/Specular Reflection Hazard)

Class 3 lasers are defined as lasers which may cause injury through intrabeam viewing or through viewing a specular reflection for less than 0.25 second. Viewing a diffuse reflection from a Class 3 laser should not cause injury to the eye. Class 3a lasers are defined as; an invisible laser with an output power which does not exceed 5 times the Class 1 AEL or a visible laser with an output power that does not exceed 5 mW. Class 3b lasers exceed the output power of Class 3a lasers but cannot exceed the upper power limit of 500 mW. All Class 3a and 3b lasers require LURs.

E. Class 4 (Diffuse Reflection and Fire Hazard)

Class 4 lasers possess the same hazards as Class 3 lasers but, because of their increased beam power (greater than 500 mW), they may also cause injury to the eye when viewing a diffuse reflection. They may present a hazard to the skin and, because of their power density, they may also present a fire hazard. All Class 4 lasers require LURs.

F. Hazard Class and the Laser Use Registration

The need for a LUR is determined by the laser's hazard class. Only Class 3a, 3b and 4 lasers and laser systems are required to have an LUR. The required hazard controls are a function of the hazard class and laser use.

Section 4: Appendices

A. Selection of Laser Safety Eyewear

B. LUR Application Form and Instructions

C. Laser Eye Exam Procedure

D. Laser Hazard Sign

E. Emergency Procedure and Emergency Contact Listing

F. Table of Typical Laser Classes

G. Laser Applications Outside the Laboratory

H. Electrical Safety Guidelines for Laser Users

I. Laser Laboratory Visitor Policy

Appendix A

Selection of Laser Safety Eyewear

(FROM ANSI)

Table 4

Simplified Method for Selecting Laser Eye Protection for Intrabeam Viewing (Wavelengths Between 0.4 and 1.4 µm).†

Q-Switched Lasers (10^{-9} - 10^{-2} s)		Non-Q-Switched Lasers (0.4×10^{-3} - 10^{-2} s)		Continuous-Wave Lasers Momentary (0.25 - 10 s)		Continuous-Wave Lasers Long-Term Staring (less than 3 hr)		Attenuation	
Maximum Output Energy (J)	Max Beam Radiant Exposure ($J \cdot cm^{-2}$)	Max Laser Output Energy (J)	Max Beam Radiant Exposure ($J \cdot cm^{-2}$)	Maximum Power Output (W)	Maximum Beam Irradiance ($W \cdot cm^{-2}$)	Maximum Power Output (W)	Maximum Beam Irradiance ($W \cdot cm^{-2}$)	Attenuation Factor	OD
10	20	100	200	10^5 *	2×10^5 *	100 *	200 *	10^8	8
1	2	10	20	10^4 *	2×10^4 *	10 *	20 *	10^7	7
10^{-1}	2×10^{-1}	1	2	10^3 *	2×10^3 *	1	2	10^6	6
10^{-2}	2×10^{-2}	10^{-1}	2×10^{-1}	100 *	200 *	10^{-1}	2×10^{-1}	10^5	5
10^{-3}	2×10^{-3}	10^{-2}	2×10^{-2}	10	20	10^{-2}	2×10^{-2}	10^4	4
10^{-4}	2×10^{-4}	10^{-3}	2×10^{-3}	1	2	10^{-3}	2×10^{-3}	10^3	3
10^{-5}	2×10^{-5}	10^{-4}	2×10^{-4}	10^{-1}	2×10^{-1}	10^{-4}	2×10^{-4}	10^2	2
10^{-6}	2×10^{-6}	10^{-5}	2×10^{-5}	10^{-2}	2×10^{-2}	10^{-5}	2×10^{-5}	10	1

† Use of this table may result in optical densities (OD) greater than necessary. See 4.6.2 for other wavelengths.

* Not recommended as a control procedure at these levels. These levels of output power could damage or destroy the attenuating material used in the eye protection. The skin also needs protection at these levels.

Appendix B

MSU LASER USE REGISTRATION (LUR) FORM

Date:________________________________ page:_____ of ______

Name of Principal Investigator____________________________________ phone #:_________________

Name of Laboratory Contacts_____________________________________ phone #:_________________

Names of Laser Users____

Department of Principal Investigator:____

Building and Room Location of Laser:____

Make/Model of Laser:____

Laser Serial Number:_________________ Type of Lasing Medium:______________________________

LASER INFORMATION

Laser Classification Marked on Laser (circle one) 3a 3b 4 none

CW

Wavelength(s): _____(nm)

Max. Op. Power: _____(W)

Avg. Op. Power: _____(W)

Pulsed

Wavelength(s): _____(nm)

Pulse durations: _____(sec)

Pulse frequency: ______(Hz)

Max. Op. Energy: ______

Avg. Op. Energy: _______

Beam Diameter at aperture: _______(mm)

Beam Divergence: __________(mrad)

Laser Use (describe briefly): ____

Please check all items that apply:

Use of Cryogens __

Use of Compressed Gases __

High Voltage Power Supplies ___

High Voltage > 30 kVp ___

Dye Laser ____

Exposed Beam Paths ___

High Noise Levels ___

Laser Cutting/Welding ___

Use of Pumping Laser ___

Beam focusing Optics ___

Fabricated Laser ___

Modified Laser ___

Freq. Doubling Crystals ___

Tunable Laser ___

Invisible Beam ___

Appendix C

Laser Eye Examination Policy and Procedure

Statement of Policy

Laser eye examinations are performed to identify those laser users which may have a predisposition for vision related injury and to meet the medical monitoring requirements of the ANSI Z136.1 Standard for the Safe Use of Lasers.

Requirement for Examinations

Those laser users who have a reasonable potential of eye exposure to Class 3b or Class 4 laser beams are required to have eye examinations within 60 days of joining the Laser Use Registration (LUR). Eye examinations will also be performed on MSU staff whenever a laser eye injury is suspected.

Responsibilities

EH&S or its designee is responsible for developing and periodically reviewing the laser eye examination policy.

EH&S is responsible for implementing the laser eye examination policy. EH&S is responsible for identifying those laser users who are required to have examinations and providing a list of those users to the Principal Investigator (PI).

EH&S is responsible for maintaining a database of laser users and when they receive the examinations.

Eye Examination Criteria

Eye examinations include the following:

Medical history of the eye and photosensitivity
Visual acuity (far and near) for both eyes
Macular function (Amsler grid)
Color vision assessment
Dilated retinal examination of both eyes
Retinal photographs of both eyes (while dilated)

Examinations will be performed by professionally qualified personnel. Patients whose results fall outside of acceptable criteria will be referred for a comprehensive examination.

Procedure

EH&S or its designee works with the PI to identify the laser users who need eye examinations and provides the PI with a written list of those users.

The PI informs the identified laser users and works with them to assure they schedule their eye examinations.

The private practitioner performs the examination and completes the approved forms which are then returned to MSU.

EH&S maintains a database of users identified and when they had their examinations.

Records

Medical records and forms returned from private practitioners are maintained by MSU. Results of examinations are the property of the person examined.

The Office of Environmental Health & Safety maintains a database of laser users and the dates on which they received examinations.

EYE EXAM FORM

Page 1
OCULAR EXAM FOR LASER USERS

Patient Note: If you have had a laser exam in the past year, it may satisfy the MSU medical surveillance requirements. Have your eyecare practitioner complete this form, which summarizes the results of your eye examination. The Section II procedures are required to be completed by your examining doctor. The Section III procedures are not required, but are recommended.

Section I: To be filled out by laser user

Name: ______________________________ Birth date: _________________________

Address: ____

Laser type and class: ____

Section II: To be filled out by the examining doctor – (Required Procedure)

Examination Date: ___________ Todays Date: _____________ Last eye exam: ________________

HISTORY

Chief Complaint: ____

____

Personal Ocular History: ____

____

Family Ocular History: ____

____

Personal systemic health history: ____

____

Medications/Allergies: ____

____

Visual Acuity:	With/Without	eyeglasses/CLs	(circle one)
Distance:	OD 20/	OS 20/	
Near:	OD	OS	

Page 2

Current eyeglasses OD ______________________

OS ______________________

Refraction OD ______________________ 20/

OS ______________________ 20/

Add ________

Amsler Grid (describe and/or enclose)

OD normal/abnormal

____

OS normal/abnormal

____

Color Vision

Method D-15/100Hue/other ______________________

Result OD ______________________

OS ______________________

Binocular vision summary ______________________

____

____

Anterior segment anomalies ______________________

____

____

Fundoscopy (with pupil dilation)

Optic nerve OD ______________________

OS ______________________

Maculae OD ______________________

OS ______________________

Periphery OD ______________________

OS ______________________

Retinal photography (35mm - enclose) ______________________

____

Section III - Optional procedures

Contrast sensitivity testing

Method ______________________________

Result OD ______________________________

OS ______________________________

Macular photostress (in seconds to recover 1 line above max VA)

OD ______________________________

OS ______________________________

Section IV Please list cause if applicable:

Vision decrease ______________________________

____

____

Amsler grid anomaly ______________________________

____

____

Color vision defect ______________________________

____

____

Any other anomalies noted ______________________________

____

____

______________________________ OD/MD
Examining doctor's signature

Appendix D
Laser Warning Sign
(from ANSI)

Appendix E
Emergency Procedure for Laser Accidents
Emergency Contact Listing

In the event of a laser accident do the following:

1) Shut down the laser system.
2) Provide for the safety of personnel (first aid, evacuation, etc.) as needed.

NOTE: If a laser eye injury is suspected, have the injured person keep their head upright and still to restrict any bleeding in the eye. Laser eye injuries should be evaluated by a physician as soon as possible.

3) Obtain medical assistance for anyone who may be injured.

Police	5222
Environmental Health & Safety	4367

4) If there is a fire, leave the area, pull the fire alarm, and contact the fire department by calling 5222. Do not fight the fire unless it is very small and you have been trained in fire fighting techniques.
5) Inform the Office of Environmental Health & Safety as soon as possible.
After normal working hours, call 5222 to contact the MSU Police Department.
6) Inform the Principal Investigator as soon as possible. If there is an injury, the PI must submit a report of injury to EH&S.
7) After an accident, do not resume use of the laser system until EH&S or its designee has reviewed the incident.

Appendix F

Table of Typical Laser Classes

(from ANSI)

Table A1

Typical Laser Classification — Continuous-Wave (CW) Lasers

Wavelength (μm)	Laser Type	Wavelength (μm)	Class 1 * (W)	Class 2 (W)	Class 3b ** (W)	Class 4 (W)
Ultraviolet 0.180 to 0.280	Neodymium:YAG (Quadrupled)	0.266 only	$\leq 9.6 \times 10^{-3}$ for 8 hours	—	> Class 1 but ≤ 0.5	> 0.5
	Argon	0.275				
Ultraviolet 0.315 to 0.400	Helium-Cadmium	0.325 only	$\leq 3.2 \times 10^{-6}$	—	> Class 1 but ≤ 0.5	> 0.5
	Argon	0.351, 0.363 only				
	Krypton	0.3507, 0.3564 only				
Visible 0.400 to 0.700	Helium-Cadmium	0.4416 only	$\leq 0.4 \times 10^{-6}$	> Class 1 but $\leq 1 \times 10^{-3}$	> Class 1 but ≤ 0.5	> 0.5
	Argon (Visible)	0.457, 0.476, 0.488, 0.514, etc				
	Krypton	0.530				
	Neodymium:YAG (Doubled)	0.532				
	Helium-Neon	0.543				
	Dye	0.400 - 0.550				
	Helium-Selenium	0.460 - 0.550				
	Helium-Neon	0.632	$\leq 7 \times 10^{-6}$			
	Dye	0.550 - 0.700	$\leq 0.4 \times 10^{-6}$ - 7×10^{-5}			
	InGaAlP	0.670	$\leq 2.4 \times 10^{-5}$			
	Ti:Sapphire	0.670	$\leq 2.4 \times 10^{-5}$			
	Krypton	0.6471, 0.6764	$\leq 1.1 \times 10^{-5}$, 3×10^{-5}			
Near Infrared 0.700 to 1.400	GaAlAs	0.780	$\leq 0.18 \times 10^{-3}$	—	> Class 1 but ≤ 0.5	> 0.5
	GaAlAs	0.850	$\leq 0.25 \times 10^{-3}$			
	GaAs	0.905	$\leq 0.32 \times 10^{-3}$			
	Neodymium:YAG	1.064	$\leq 0.64 \times 10^{-3}$			
	Helium-Neon	1.080, 1.152 only	$\leq 0.64 \times 10^{-3}$			
	InGaAsP	1.310	$\leq 4.40 \times 10^{-3}$			
Far Infrared 1.400 to 10^3	InGaAsP	1.550	$\leq 9.6 \times 10^{-3}$	—	> Class 1 but ≤ 0.5	> 0.5
	Holmium	2.100				
	Erbium	2.940				
	Hydrogen Fluoride	2.600 - 3.000				
	Helium-Neon	3.390 only				
	Carbon Monoxide	5.000 - 5.500				
	Carbon Dioxide	10.6				
	Water Vapor	118	$\leq 9.5 \times 10^{-2}$			
	Hydrogen Cyanide	337				

* Assumes no mechanical or electrical design incorporated into laser system to prevent exposures from lasting to T_{max} = 8 hours (one workday); otherwise the Class 1 AEL could be larger than tabulated.

** See 3.3.3 for definition of Class 3a.

Table A2

Typical Laser Classification — Single-Pulse Lasers

Wavelength (µm)	Laser Type	Wavelength (µm)	Pulse Duration (s)	Class 1 (J)	Class 3b (J)	Class 4 (J)
Ultraviolet 0.180 to 0.400						
	Excimer (ArF)	0.193	20×10^{-9}	$\le 1.9 \times 10^{-4}$ *	> Class 1 but ≤ 0.125	> 0.125
	Excimer (KrF)	0.248	20×10^{-9}	$\le 1.9 \times 10^{-6}$ *	> Class 1 but ≤ 0.125	> 0.125
	Neodymium:YAG Quadrupled (Q-sw)	0.266	20×10^{-9}	$\le 1.9 \times 10^{-6}$ *	> Class 1 but ≤ 0.125	> 0.125
	Excimer (XeCl)	0.308	20×10^{-9}	$\le 4.3 \times 10^{-6}$ *	> Class 1 but ≤ 0.125	> 0.125
	Nitrogen	0.337	20×10^{-9}	$\le 3.6 \times 10^{-6}$ *	> Class 1 but ≤ 0.125	> 0.125
	Excimer (XeF)	0.351	20×10^{-9}	$\le 4.3 \times 10^{-6}$ *	> Clas 1 but ≤ 0.125	> 0.125
Visible 0.400 to 0.700						
	Rhodamine 6G (Dye Laser)	0.450-0.650	1×10^{-6}	$\le 0.2 \times 10^{-6}$	> Class 1 but ≤ 0.03	> 0.03
	Copper Vapor	0.510, 0.578	25×10^{-9}	$\le 2 \times 10^{-7}$	> Class 1 but ≤ 0.03	> 0.03
	Neodymium:YAG Doubled (Q-sw)	0.532	20×10^{-9}	$\le 2 \times 10^{-7}$	> Class 1 but ≤ 0.03	> 0.03
	Ruby (Q-sw)	0.6943	20×10^{-9}	$\le 2 \times 10^{-7}$	> Class 1 but ≤ 0.03	> 0.03
	Ruby (Long Pulse)	0.6943	1×10^{-3}	$\le 4 \times 10^{-6}$	> Class 1 but ≤0.03	> 0.03
Near Infrared 0.700 to 1.4						
	Ti:Sapphire	0.700-1.000	6×10^{-6}	$\le 1.9 \times 10^{-7}$	> Class 1 but ≤ 0.03 C_A	>0.03 C_A
	Alexandrite	0.720-0.800	1×10^{-4}	$\le 0.76 \times 10^{-6}$	> Class 1 but ≤ 0.03 C_A	>0.03 C_A
	Neodymium:YAG (Q-sw)	1.064	20×10^{-9}	$\le 2 \times 10^{-6}$	> Class 1 but ≤ 0.15	> 0.15
Far Infrared 1.4 to 10^3						
	Erbium:Glass (Q-sw)	1.540	10×10^{-9}	$\le 7.9 \times 10^{-3}$	> Class 1 but ≤ 0.125	> 0.125
	Co:Magnesium-Fluoride	1.8-2.5	80×10^{-6}	$\le 7.9 \times 10^{-4}$	> Class 1 but ≤ 0.125	> 0.125
	Holmium	2.100	250×10^{-6}	$\le 7.9 \times 10^{-4}$	> Class 1 but ≤ 0.125	> 0.125
	Hydrogen Fluoride	2.600-3.000	0.4×10^{-6}	$\le 1.1 \times 10^{-4}$	> Class 1 but ≤ 0.125	> 0.125
	Erbium	2.940	250×10^{-6}	$\le 5.6 \times 10^{-4}$	> Class 1 but ≤ 0.125	> 0.125
	Carbon Dioxide (Q-sw)	10.6	100×10^{-9}	$\le 7.9 \times 10^{-3}$	> Class 1 but ≤ 0.125	> 0.125
	Carbon Dioxide	10.6	1×10^{-3}	$\le 7.9 \times 10^{-4}$	> Class 1 but ≤ 0.125	> 0.125

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

Appendix G

Laser Applications Outside the Laboratory

Introduction

The use of a laser outside of a controlled area can present special hazards to the campus community and to the general public. This appendix addresses the control of any laser (Class 3a, 3b, or 4) used outside the normal research laboratory environment. These applications may include; lasers used for telecommunications, laser research being performed outdoors, and lasers used for entertainment or public viewing.

Applicability

Any laser (Class 3a, 3b, or 4) used for entertainment, displays, demonstrations, or any related use intended for public viewing (indoors or outdoors) shall be operated in accordance with federal, state, local, and campus regulations/requirements.

The operators of laser systems used for entertainment are required by law to file a "Report on Laser Light Show Display" (or a variance document), with the Food and Drug Administration's Center for Devices and Radiological Health (FDA/CDRH). If the venue is outdoors and the beam(s) may terminate in navigable airspace, then the operators are also required to file a report with the Federal Aviation Administration (FAA) office.

All Class 3a, 3b, or 4 laser systems being used on MSU property must be used in accordance with the campus Laser Safety Program. Any variation from the Laser Safety Program must be approved by EH&S or its designee.

Procedures

Performances, campus departments, or campus-affiliated group (student or otherwise) shall notify EH&S or its designee of any laser light show (indoor or outdoor) to be performed on MSU property. EH&S or its designee will request from the light show operators a copy of the CDRH required "Report on Laser Light Show Display" (or variance document) prior to the show. Upon receipt, EH&S or its designee shall review the description of the show and the operator’s safety procedures. EH&S or its designee may require additional safety measures to assure the safety of the operators, performers, or audience.

The Principle Investigator (PI) shall inform EH&S or its designee of any lasers used outdoors for research projects. Such laser uses will need to be covered under a LUR. The application and operation of the laser system(s)shall be evaluated by EH&S or its designee to ensure that appropriate safety measures are in place prior to operation.

Laser Safety Requirements - Laser Light Shows

NOTE: A LUR is not normally required for laser light shows.

- The CDRH and ANSI requirements specified by EH&S or its designee must be met.
- Any audience exposure to laser radiation must not exceed the ANSI Class 1 limit.
- Operators, performers, and employees must be able to perform their duties without having to directly view laser radiation exceeding the ANSI Class 1 limit, and without being exposed to laser radiation exceeding the ANSI Class 2 limit.
- All laser scanners (including mirror balls) must incorporate proper scanning safeguards.
- If the laser is not under continuous operator control, any Class 3a, 3b, or 4 level of laser radiation cannot be closer than 6 m vertically or 2.5 m horizontally from any standing surface or standing position where the audience may be located.
- If the laser is under continuous operator control, any Class 3a, 3b, or 4 level of laser radiation cannot be closer than 3 m vertically or 2.5 m horizontally from any standing surface or standing position where the audience may be located.
- An operator with an accessible control to terminate the beam must be available if conditions become unsafe.
- FAA notification is required (for Class 3a, 3b, and 4 lasers) if the display is being used in navigable airspace.
- Additional safety requirements may be needed as specified by EH&S or its designee.
- The CDRH "Report on Laser Light Show Display" forms are available from EH&S or its designee.

Laser Safety Requirements - Other Outdoor Uses of Laser

NOTE: A LUR is required for the use of a Class 3a, 3b, or 4 laser.

- Meet the specified LUR safety requirements.
- EH&S or its designee will establish a Nominal Hazard Zone (any area where the maximum permissible exposure (MPE) is exceeded).
- The NHZ must be posted and/or restricted as directed by EH&S or its designee.
- The PI must ensure that only trained personnel enter the NHZ, and that appropriate PPE (personal protective equipment) is issued and used.
- The PI must ensure users are properly trained and meet the campus laser safety training requirements.
- The PI must ensure only authorized personnel are allowed to operate the laser.
- The PI must ensure the use of any required administrative/engineering controls.
- Laser beams shall not be directed toward structures, automobiles, aircraft, or other vehicles within the NHZ unless adequate training and protective equipment is provided and used by all personnel within these structures/vehicles.

- The laser beam path shall not be maintained at eye level without EH&S or its designee approval.
- FAA notification is required (for Class 3a, 3b or 4 lasers) if the laser is being used in navigable airspace.
- Additional safety requirements may be needed as specified by the LSO.

Policy Exceptions

Any exceptions to this policy must be approved by EH&S or its designee. Contact the EH&S at 4367 if you need exemption from this policy.

Emergencies

The potential for injuries from a laser light show/display is minimal if the operators observe the CDRH requirements. In the event that an individual suspects an eye injury, the operators of the laser system shall be notified immediately so that the laser beam(s) can be terminated. The event staff shall also be notified and medical attention shall be provided to the injured individual if needed. EH&S shall be informed as soon as possible should any laser injury be suspected.

Regulatory References

- Food and Drug Administration's Center for Devices and Radiological Health (FDA/CDRH)
- Federal Aviation Administration (FAA)
- American National Standards Institute (ANSI) Z136.1 (1993) - Safe Use of Lasers

Appendix H

Electrical Safety Guidelines for Laser Users

Electrical Hazards and Laser Users

Laser systems and power supplies normally require thousands of volts and tens of amperes to operate. The electrical needs associated with laser use present inherent electrical safety hazards.

These hazards are normally mitigated by the engineering controls (enclosures, interlocks, grounding, etc.) built into the laser systems. However, if these engineering controls are defeated during tuning or maintenance, live contacts can be directly accessed. Contact with these may cause any number of adverse bio-effects, up to and including death by electrocution.

There are at least 15-recorded instances of electrocution directly attributed to laser systems. It is essential that laser users be aware of and protect themselves from the electrical hazards found in laser facilities.

Electrical Terminology

a. Alternating Current (AC) - A current that reverses polarity with a given frequency expressed in cycles/second or Hertz (Hz). US wall current is 60 Hz AC.

b. Amperage (I) - the current (number of electrons) flowing in a circuit (measured in Amperes or Amps).

c. Conductor - a material that has a normally low resistance.

d. Direct Current (DC) - A current with a fixed polarity normally associated with batteries or rectified AC current.

e. Electrical Ground - AC circuits usually contain a third conductor that provides a pathway to ground should a short circuit occur. NOTE: the electrical ground is intended to protect equipment and prevent fires, it is not intended to protect persons from shock hazards.

f. Insulator (dielectric)- a material which has a normally high resistance.

g. Ohms Law - Amperage is equal to voltage divided by the resistance and expressed in the formula $I = V / R$.

h. Resistance (R) - the ability of a material to allow the flow of electrons (measured in Ohms or W).

i. Short Circuit - When current is allowed to take an unintended path back to its source. If that path runs through a person, serious injury or death can result.

j. Voltage (V) - the potential (energy of the electrons) flowing in a circuit (measured in Volts).

k. Wattage (W) - the unit of power, devices are often rated as to the power in Watts required for their operation ($W = V \times I$).

<u>Materials That Are Good Conductors</u>

Materials that are good conductors include: precious metals, copper, aluminum, other elemental metals and alloys, and ionic liquids (especially water containing dissolved salts). Both tap water and human bodily fluids are considered ionic liquids.

<u>Materials That Are Good Insulators</u>

Materials that are good insulators include: rubber and most plastics, dry wood, ceramics, fiberglass, organic materials, and non-ionic liquids (like distilled water).

<u>Sources of Electrical Hazards in Laser Facilities</u>

a. Common AC wall current at 120 volts.

b. Specialty AC wall current of 240 or 480 volts.

c. High voltage (> 600 volts) AC supplies.

d. DC power supplies (including batteries and capacitors).

e. Static electricity (NOTE: spark temperatures exceed 1000 deg. F and can ignite solvents used for cleaning or for laser dyes).

<u>Examples of Electrical Hazards in Laser Facilities</u>

a. <u>Electrical supply boxes.</u> These boxes may be left open and/or unlatched. Combustible materials must have a 3-foot separation distance from the boxes as required by OSHA.

b. <u>Wall sockets, power plugs, power cables and couplings.</u> Wall sockets may not be properly wired. Power plugs may have exposed conductors if they are damaged. Power cables and couplings are not only a tripping hazard but may have exposed conductors if they are damaged by foot and cart traffic.

c. <u>Lasers, power supplies, and other lab equipment.</u> Laser housings contain high voltage/amperage, which can be directly accessed if the covers are removed. Power supplies often contain large capacitors that can retain a lethal charge even after the laser is turned off or unplugged.

d. <u>Ungrounded laser systems and optical tables.</u> Failure to maintain proper grounding of lasers and optical tables can allow short circuit conditions to endanger persons who contact the laser or optical table.

e. <u>Home or shop made electrical components.</u> Often built without a knowledge of electrical safety codes, home built equipment can be improperly grounded, not have sufficient safety enclosures, etc. Research equipment must be constructed with components that have been tested by a recognized testing organization (e. g. Underwriter's Laboratory). For assistance in evaluating equipment, contact the Office of Environmental Health & Safety (EH&S).

f. <u>Jewelry.</u> Care should be taken not to wear metal jewelry (gold, silver) around laser systems or power supplies. In addition to their highly conductive electrical properties, metal jewelry can also present a specular beam reflection hazard.

g. <u>Special situations that could create short circuits to ground.</u> Should there be a cooling water leak that contacts a hot conductor, the current will flow through the liquid to ground. Persons in contact with the spilled water could become part of the circuit.

Types of Electrical Hazards

a. Shock - If the human body becomes part of the circuit, current will flow through various organs (depending on the pathway). If current flows through the human heart, it may cause fibrillation (abnormal muscle contractions) that can result in death.

b. Arc - The flash ionization of air resulting from direct flow of high current from one conductor to another. The resulting vaporization of materials (like conductors) creates a plasma with an extremely high temperature (as high as 50,000 deg. C) which can ignite combustible materials at several meters and cause severe burns to tissue.

c. Blast - The pressure transient resulting from plasma arc vaporization of materials (mainly metal conductors). This blast has been known to cause severe injury through the transfer of kinetic energy to objects and persons.

d. Fire - Combustion of materials from electrical sources can cause injuries and destroy property.

Electrical Exposure Bio-effects

a. Cardiac fibrillation - disruption of the heart rhythm, either immediate or delayed (the major cause of death from electrical shock).

b. Internal (organ) burns - often resulting in amputations or death.

c. External (skin) burns - usually caused by metals melted/vaporized by an arc.

d. "Blow out" injuries - from vaporized body fluids caused by current flow in tissues.

e. Neurological damage - either immediate or delayed (can be very severe).

f. Physical shock - usually related to trauma (complicates other injuries).

g. Psychological trauma - common with severe injury.

h. Blast related physical trauma injuries - broken bones, internal bleeding, etc.

i. Electrical shock associated injuries - falls, etc.

j. Death - by electrocution (about 500 deaths per year in the U.S. from all electrical sources).

k. Other deaths related to electricity - fatal fires, contact with moving parts, etc. (accounts for about 1000 deaths per year).

Relative Bio-effects Resulting from Exposure to Increasing AC Voltage

50 V (or less)	Little shock hazard unless the skin surfaces are wet.
75 V	Dry skin provides almost no protection from shock.
120 V	Standard US wall plug voltage (causes most deaths).
240 V	Highest common wall voltage normally used in US.
480 V	Voltage from step-down transformer (not as common).
> 600 V	Skin resistance breaks down, allowing current into tissues (definition of high voltage).
2300 V	Arcing to skin occurs, preventing direct contact to source.
> 2400 V	Burning of tissues is the major bio-effect.

Relative Bio-effects Resulting from Exposure to Increasing Current

0.5 mA	No sensation usually felt with contact.
1.0 mA	Slight tingling felt with contact (perception threshold).
1.5 mA	Shock clearly felt (no pain or loss of muscle control).
7.5 mA	Painful shock (no loss of muscle control).
10 mA	Let-go threshold (loss of muscle control).
20 mA	Severe shock, hard to breath, severe muscle contractions.
30 mA	Respiratory paralysis (frequently fatal if no CPR).
75 mA	Fibrillation threshold for 0.5% of exposed persons.
250 mA	Fibrillation threshold for 99.5% of exposed persons.
4 A	Heart paralysis threshold (no fibrillation, may restart spontaneously).
> 5 A	Burning of tissue (could be fatal if vital organs are damaged).
15 A - 20	A Normal amperage in US 120 V wall circuit.
30 A - 50	A Normal amperage required for ion laser operation.

Components of a Good Electrical Safety Program

a. Qualification of Workers - Work on electrical equipment can only be performed by "qualified" personnel (OSHA requirement). These personnel must be properly trained in electrical safety practices and procedures and must be approved by their department to work on electrical equipment. It is essential that you do not work on electrical equipment if you are unfamiliar with electrical devices or if you are untrained in electrical safety.
b. Lock-Out/Tag-Out (LOTO) Procedures - As required by state and federal law, the campus has established LOTO procedures to allow for the safe installation, service, maintenance, adjustment, or other handling of laser systems and other powered equipment.
These LOTO procedures apply whenever the unexpected energizing of the equipment or release of stored energy (such as from charged capacitors) could cause injury. Equipment which has the potential to be energized must be properly locked and/or tagged out in accordance with the campus procedure if:

- A person may contact energized components while performing the work.
- A person is required to remove or bypass any guard, interlock, or other safety device (including equipment covers) to perform the work.
- A person is required to place any part of his or her body into an area on the equipment (or piece of machinery) where work is performed during the equipment's operation.

To obtain a copy of the campus LOTO procedures, please contact the campus Office of Environmental Health and Safety at 4367.

c. "Energized Work" Procedures - If the equipment can only be serviced or adjusted while energized, special "energized work" procedures, testing equipment, special tools, and personal protective equipment may be required. In these cases, special controls may be necessary to insure safety. These controls may include; the use of ground fault circuit interrupter (GFCI), insulated tools, and/or trained stand-by personnel. In accordance with the campus LOTO procedures, all "energized work" procedures must be approved by the campus Office of Environmental Health and Safety prior to beginning the work.

(Note: LOTO procedures should always be followed unless it is physically impossible to conduct the work without the equipment being energized. Only in such instances are "energized work" procedures allowed.)

d. Other Issues - All electrical hazards should be properly marked and/or labeled. Proper switching and grounding techniques must be learned and practiced. The OSHA required work clearances around energized panels must be maintained.

Appendix I

Laser Laboratory Visitor Policy

Definitions:

- A laboratory visitor is any person who is present in the laboratory as an invited guest of any MSU employee or student researcher.
- Visitors who are to be in the laboratory for a period of more than one day but less than one month are considered short-term researchers.
- Persons who will be in the laboratory for a period of more than one month are considered to be campus laser users.
- The Office of Environmental Health & Safety works with the Principal Investigators and laser users to ensure that the visitor policy is properly enforced.

Visitor Policy and Requirements:

It is the policy of the MSU EH&S to require the same level of laser laboratory safety for all visitors and short-term researchers as is required for laser users. All visitors and short-term researchers are to be escorted by a person whose name appears on the Laser Use Registration (LUR) as a laser user. If it is necessary for a short-term researcher to work alone in the laser laboratory, the individual must be added to the LUR as a laser user.

It is the responsibility of the Principal Investigator to assure that his/her laser users are informed of, understand, and follow this visitor policy.

It is the responsibility of the visitor's laser user escort to provide the visitor with an appropriate safety orientation covering the hazards in the laser laboratory. The escort shall also provide appropriate safety equipment and require the safety equipment be used by the visitor.

Short-term researchers must meet the same laser safety-training requirement as campus laser users (but do not need to be added to the LUR). Laser users must be immediately added to the LUR as specified in the Laser Safety Manual.

As a reminder, no unregistered use of any laser is allowed under any circumstances. The LUR indicates the registered use(s) of the laser system. All LUR and MSU Laser Safety Policy requirements must be followed at all times. No intra-beam viewing of any laser is allowed under any circumstances by any person.

It is the responsibility of the Principal Investigator to assure that persons who are not invited into the laser laboratory or who fail to follow direction regarding safety policy or the use of safety equipment are immediately escorted from the laser facility.

Visitor Recommendations:

Although it is primarily the responsibility of the escort to provide a safe environment for laboratory visitors, consideration should be given to the following:

- Unless it is absolutely necessary to have the laser energized during the visit, it is recommended that all lasers and laser power supplies be turned off and the activation keys removed during the visit.
- Research environments can prove very hazardous to children. It is recommended that all persons under the age of 18 not be allowed into any laboratory.
- It is recommended that any laser demonstration be conducted so that the laser beam is directed away from any visitor, regardless of the laser eye protection being used.

Patients and Visitors Exposed to Medical Lasers:

- Except as required for medical treatment or the instruction of medical staff, every effort should be made to limit the presence of visitors in the laser treatment room.
- Except as required for medical treatment of the eye, appropriate beam management shall be practiced to prevent eye exposure from any medical laser.
- Persons not receiving laser eye treatment who are present in the laser treatment room shall be provided, instructed in the use, and required to use appropriate laser eye protection.

Laser Safety Training Supplement

Section 1: MSU Laser Safety Program

A. Laser Safety Policy Manual

B. Laser Safety Training Requirements

Section 1 - MSU Laser Safety Program

This supplement is intended to give the reader a basic understanding of lasers and laser safety. The MSU Laser Safety Program requires laser users to read and use the information in this supplement.

A. Laser Safety Manual

Your Principal Investigator (PI) has a copy of the MSU Laser Safety Manual available for your reference. You should review the manual prior to starting work covered by the Laser Use Registration (LUR).

B. Laser Safety Training Requirements

All laser users are required to read the Laser Safety Training Supplement and the Laser Use Registration (LUR) for the laser(s) they use. They are required to certify (by signature) that they have read the documents. The training certificate can be found in Appendix A. Each laser user must return a signed copy of the training certificate to the Office of Environmental Health & Safety.

Section 2: The Unique Nature of Laser Radiation

A. Coherent vs. Non-coherent Radiation Sources
B. Monochromatic Radiation Sources
C. Irradiance (Power Density) and Continuous Wave Lasers
D. Radiant Exposure (Energy Density) and Pulsed Lasers

Section 2 - The Unique Nature of Laser Radiation

A. Coherent vs. Non-Coherent Radiation Sources

The laser is unique in that it creates a radiation beam that is coherent (in-phase). In a coherent light source, the amplitude of the radiated waves is added (constructive interference) and results in a radiation beam of great intensity. Non-coherent radiation sources (like a light bulb) produce radiation that is out of phase. This results in the reduction of the amplitude by cancellation of overlapping wave forms (destructive interference). The intensity of coherent radiation sources normally exceeds the intensity of non-coherent sources by orders of magnitude.

B. Monochromatic Radiation Sources

Many sources produce a broad range of radiation wavelengths. Lasers will normally produce only one or two wavelengths. The single wavelength is called monochromatic radiation and, depending on the type of laser, the radiation produced can fall anywhere in the electromagnetic spectrum between 10 nm (extreme ultraviolet) and 1 mm (far infrared). Monochromatic radiation does not scatter much (as does polychromatic radiation) when interacting with lenses or mirrors (chromatic aberration). This reduction in scattering can result in very intense specular or diffuse reflections.

C. Irradiance (Power Density) and Continuous Wave (CW) Lasers

An important factor in determining the hazard of continuous wave lasers is the irradiance (power density) of the laser beam. Irradiance is normally expressed in W/cm2 and is a function of the beam power divided by the beam area. Beam area is dependent on: the beam size at the aperture, the divergence (spreading) of the beam and the distance from the aperture. Focusing or defocusing the laser will dramatically affect the irradiance. Obviously, the greater the irradiance, the greater the potential hazard.

D. Radiant Exposure (Energy Density) and Pulsed Lasers

Not all lasers are operated in a continuous wave mode. Many operate in a pulsed mode with a pulse duration and a pulse repetition frequency. These lasers cannot be characterized by their irradiance and we instead refer to their radiant exposure (energy density), which is expressed in J/cm2. Radiant exposure is a function of power density, pulse duration and pulse frequency. Again, the greater the radiant exposure, the greater the hazard. The averaged power (pulses/sec x J/pulse = J/sec or Watts) of a pulsed laser will usually be less than a CW laser, however the peak power in the pulse may be very large if the pulse duration is very short.

Section 3: Understanding the Laser

Section 3 - Understanding the Laser

A. Basic Operation of the Laser

The basic operating concept of the laser is very simple. Electrons in the atoms of the lasing medium are moved from a ground state into a higher energy state by absorbing energy from an energetic excitation source. For the laser to work, more electrons must be an excited state than in a ground state (population inversion). When these electrons descend to their ground state, photons of a specific (monochromatic) wavelength are emitted in a process called "spontaneous emission." These photons are allowed to oscillate inside a mirrored resonator. This increases the laser radiation intensity through stimulating the emission of additional photons with the same wavelength and phase. Finally, the photons are allowed to escape via an output coupler (semi-mirrored mirror) as an intense laser beam (see Diagram #1).

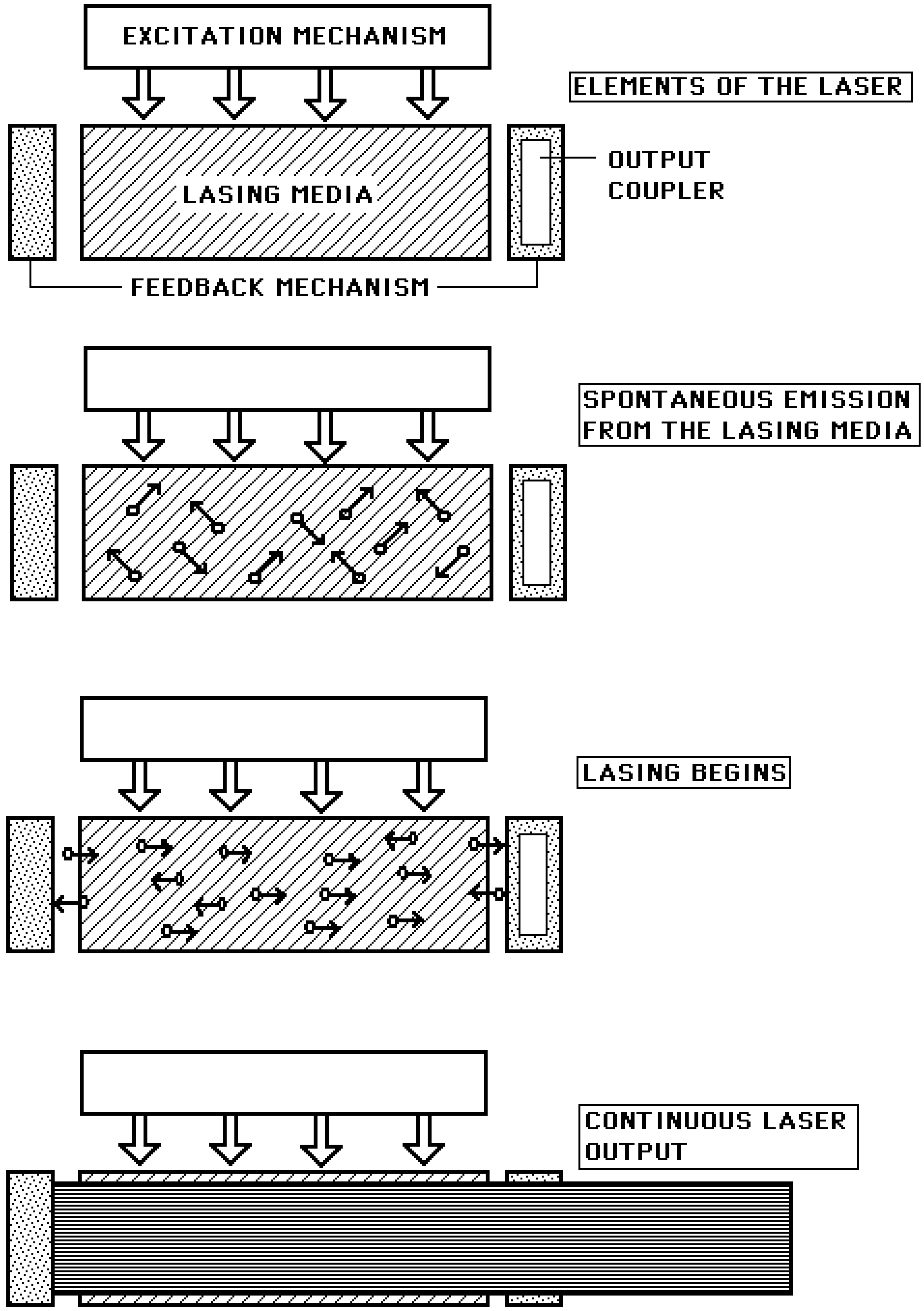
B. Types of Lasing Media

Lasing media can be solids, liquids, or gases. The type of medium dictates the wavelength of the laser beam. Some media can be manipulated to allow for tuning of the wavelength. Solid-state media (polished crystal rods), gases or vapors (sealed in a glass tube), liquid dyes, and semiconductors (laser diodes) are all common lasing media. Halogen gases mixed with noble gases can combine in an excited state to create pseudo molecules called "excited dimmers" or excimers. Excimer lasers emit laser radiation in the ultraviolet region of the spectrum. It is also possible to use an accelerated beam of free electrons as a lasing media. Free electron lasers (FEL) use a "wiggler" magnet to propagate photons from the electron beam. See Appendix C for a listing of laser types (media) typically found at NJIT.

C. Types of Excitation Sources

Flash lamps, plasma discharge tubes, high voltage current and radio frequency devices are all energy sources used to excite the lasing media. Some laser beams are used to "pump" (excite) other lasers (liquid dyes, Ti-Sapphire, etc.). It is important to remember that the excitation device itself can present a serious non-beam hazard (radiation, electrical, etc.).

DIAGRAM #1


EXCITATION MECHANISM
ELEMENTS OF THE LASER
LASING MEDIA
OUTPUT
COUPLER
FEEDBACK MECHANISM
SPONTANEOUS EMISSION
FROM THE LASING MEDIA
LASING BEGINS
CONTINUOUS LASER
OUTPUT

Section 4: Laser Radiation Bio-effects

Section 4 - Laser Radiation Bio-effects

A. Tissues at Risk and Mechanisms of Injury

The tissues that are normally considered to be at risk are the eyes and the skin. There are three primary mechanisms of tissue injury associated with laser radiation exposure. These are; thermal effects, photochemical effects, and acoustical transient effects (eye only).

- Thermal effects can occur at any wavelength and are a function of the irradiance or radiant exposure and the blood flow cooling potential of the tissue.
- In air, photochemical effects occur between the 200 to 400 nm ultraviolet and the 400 to 470 nm "blue light" wavelengths. Photochemical effects are related to the duration and repetition of the exposure as well as related to the irradiance or radiant exposure.
- Acoustical transient effects are related to pulse duration and may occur in short duration pulses (up to 1 ms), depending on the specific wavelength of the laser. The acoustical transient effect is poorly understood, but it can cause retinal damage that cannot be accounted for by thermal injury alone.

B. Eye Injury Potential

The potential location of injury in the eye (see Appendix E - Eye Component Diagram) is directly related to the wavelength of the laser radiation. For laser radiation entering the eye:

- Wavelengths shorter than 300 nm or longer than 1400 nm are absorbed in the cornea.
- Wavelengths between 300 and 400 nm are absorbed in the aqueous humor, iris, lens, and vitreous humor.
- Wavelengths between 400 nm and 1400 nm are focused onto the retina.

NOTE: Laser retinal injury can be severe because of the focal magnification (optical gain) of the eye, which are approximately 105. This means that an irradiance of 1 mW/cm2 entering the eye will be effectively increased to 100 W/cm2 when it reaches the retina.

Thermal burns (lesions) in the eye are caused when the choroids layer blood flow cannot regulate the heat loading of the retina. Secondary bleeding into the vitreous humor may occur as a result of burns that damage blood vessels. This bleeding can obscure vision well beyond the area of the lesion.

Although the retina can repair minor damage, major injury to the macular region of the retina may result in temporary or permanent loss of visual acuity or blindness. Photochemical injury to the cornea by ultraviolet exposure may result in photokerato conjunctivitis (often called welders flash or snow blindness). This painful condition may last for several days and is very debilitating. Long term UV exposure can cause cataract formation in the lens (see Appendix F – Bio-effects Chart).

The duration of exposure also plays a role in eye injury. For example, if the laser is a visible wavelength (400 to 700 nm), the beam power is less than 1.0 mW and the exposure time is less than 0.25 second (the human aversion response time), no injury to the retina would be expected to result from an intrabeam exposure. Class 1, 2a and 2 lasers fall into this category and do not normally present a retinal hazard. Unfortunately, intrabeam or specular reflection viewing of Class 3a, 3b, or 4 lasers and diffuse reflections from Class 4 lasers may cause an injury before the aversion response can protect the eye.

For pulsed lasers, the pulse duration also effects the potential for eye injury. Pulses less than 1 ms in duration focused on the retina can cause an acoustical transient, resulting in substantial damage and bleeding in addition to the expected thermal injury. Many pulsed lasers now have pulse duration less than 1 pico second.

The ANSI Z136.1 standard defines the Maximum Permissible Exposure (MPE) that the eye can receive without expecting an eye injury (under specific exposure conditions). If the MPE is exceeded, the probability that an eye injury can result increases dramatically.

The first rule of laser safety is: NEVER UNDER ANY CIRCUMSTANCES LOOK INTO ANY LASER BEAM! If you can prevent the laser beam and beam reflections from entering the eye, you can prevent a painful and possibly blinding injury.

C. Skin Injury Potential

Skin injuries from lasers primarily fall into two categories: thermal injury (burns) from acute exposure to high power laser beams and photo chemically induced injury from chronic exposure to scattered ultraviolet laser radiation.

- Thermal injuries can result from direct contact with the beam or specular reflections. These injuries (although painful) are usually not serious and are normally easy to prevent through proper beam management and hazard awareness.

- Photochemical injury may occur over time from ultraviolet exposure to the direct beam, specular reflections, or even diffuse reflections. The effect can be minor or severe sunburn, and prolonged exposure may promote the formation of skin cancer. Proper protective eyewear and clothing may be necessary to control UV skin and eye exposure.

Section 5: Laser Beam Hazards and Control Methods

A. Administrative Controls

1. Standard Operating Procedures (SOPs)
2. Posting and Labeling of Laser Systems

B. Engineering Controls

1. Controlling Access to Laser Facilities
2. Protective Housings, Interlocks and Shutters

Section 5-Laser Beam Hazards and Control Methods

General Considerations

The primary hazard associated with the laser is eye injury caused by intrabeam viewing or the viewing of specular or diffuse reflections. Hazard controls are primarily intended to prevent the laser beam from entering the eye or contacting the skin. These control methods are divided into three areas: administrative controls (signs, labels, procedures, etc.), engineering controls (barriers, beam blocks, interlocks, etc.), and personal protective equipment (laser protective eyewear, skin covering, etc.).

Experience has shown that reliance on any one of these control methods is not as effective as using a combination of the methods. For this reason, the MSU Laser Safety Program requires the use of a broad range of controls.

A. Administrative Controls

Administrative controls are useful in promoting laser safety in the laboratory. Each specific LUR provides information on the administrative controls to be used for the laser.

1. Standard Operating Procedures (SOPs)

The Laser Safety Program requires the development, documentation, and use of SOPs for alignments, maintenance and normal operations. These SOPs are the logical place to document in-house administrative controls. The SOPs should then be used to train laser users in the facility.

It must be stressed that administrative controls will not positively impact the laser safety environment unless they are kept up-to-date and are reinforced by the PI through example and action.

2. Posting and Labeling of Laser Systems

The posting and labeling of laser hazards on campus is intended to comply with the ANSI Z136.1 laser safety standard and the FDA/CDRH laser performance standard.

All access doors to rooms which contain Class 3a, 3b, or 4 lasers are to be posted with a sign marked with the word "**DANGER**", the international laser symbol, a description of the laser class, the wavelength, and the laser power (as specified in the ANSI Z136.1 laser safety standard). A room containing more than one laser may include information for several lasers on the same sign. For some Class 3b or 4 laser systems, EH&S may require that an interlocked lighted sign (that blinks on and off when the laser is operating) be located outside of the laser facility to further warn staff of the presence of laser radiation.

All Class 3a, 3b, and 4 lasers are required to be marked with the appropriate labels indicating the laser class, laser hazard, and identifying the laser aperture (as specified in the FDA/CDRH laser performance standards). The appropriate labels are available from ORS.

B. Engineering Controls

1. Controlling Access to Laser Facilities

All Class 3b and 4 laser facilities are required to have appropriate access controls to prevent unauthorized personnel from entering the facility while the laser is in operation. Key or combination locks are appropriate for this purpose. Doorways to laser facilities are to be kept closed at all times, and locked when the laser user is not in direct attendance. The EH&S may require that the doorways to the laser facility be properly interlocked to the laser shutter if it becomes apparent that locked doors alone can not meet access control requirements. If a door interlock is required, it must not be disabled except with the approval of EH&S or its designee.

2. Protective Housings, Interlocks and Shutters

All Class 3a, 3b, and 4 lasers are required to have a non-combustible protective housing sufficient to contain the beam and excitation device. It is strongly recommended that the housing be interlocked so that the laser cannot normally be operated with the cover removed. If a housing interlock is required, it must not be disabled except with the approval of EH&S or its designee.

Most Class 3b and 4 lasers are equipped with a shutter mechanism that prevents the beam from leaving the housing when activated. If the laser has a shutter, it is not to be disabled except with the approval of EH&S or its designee.

3. Key Operation, Power On Indication, and Power Meters

Many laser systems are equipped with key switches that prevent operation when the key is removed. If a key switch is required, it must not be disabled except with the approval of EH&S or its designee. In order to prevent unauthorized personnel from operating the laser, the key should be removed from the laser control and stored in a secure location whenever the laser is not being used.

All class 3b and 4 lasers need to have a lighted "power on" indicator clearly visible to persons in the laser facility. The "power on" indicator should be interlocked to prevent the laser from being operated if the indicator is not functioning.

It is highly recommended that each laser system have a power meter available to measure the operating power of the laser.

4. Optical Tables, Beam Alignment and Remote Viewing Systems

Most research laser use entails the use of optical tables and optical devices to manipulate beams. To assure a safe laser-operating environment, the optical components and the optical table environment must be evaluated for hazards. The primary intent of this evaluation is to prevent the laser beam from leaving the table top. Optical components must be aligned and properly secured to assure beam control. Be aware of secondary reflections from optical devices by performing physical surveys and assure all stray beams are properly contained.

Beam height should be planned to avoid eye level (both standing and sitting) in the laser facility. In situations where the beam needs to be directed to another area, it is important to consider enclosing the beam, using fiber optics, or directing the beam well above eye level as a precaution against accidental exposure. Beams being directed between optical tables must employ a properly marked physical barrier to prevent personnel contact with the beam.

Beam alignment is the most hazardous aspect of laser use and most laser eye injuries occur during alignments. For this reason, beam alignment standard operating procedures (SOP) must be carefully thought out, documented, and users properly trained on the procedures. Beam alignment should be performed at the lowest visible beam power.

Alignments are normally performed by carefully fixing a diffuse reflecting card in the beam path, turning the beam power up slowly till the beam can just be imaged and carefully aligning the optical components. If the beam is invisible, UV or IR cards or viewers may be required to image the beam. NOTE: IR and UV viewers do not protect the eye and must be used with appropriate laser eye protection.

NOTE: Intrabeam (on-axis) viewing of laser beams is not normally allowed on the MSU campus. In certain circumstances, intrabeam viewing may be allowed with the direct written permission of EH&S or its designee.

If the beam power cannot be reduced, it is recommended that a low powered alignment laser (Class 2/3a HeNe or diode) be used to align the optics. If alignments are being done with power levels above the MPE, the user is required to use appropriate laser protective eyewear during the procedure. This eyewear will normally be of minimal optical density (OD) at the wavelength of interest. This will enable viewing of a diffuse reflection of the beam while providing some protection from a momentary specular reflection (intrabeam viewing is not allowed). Alignments must be done so that the user is never looking directly into the beam.

When possible, it is advisable to have two users work together when performing alignments to remind each other of safety considerations. One of the safest methods to use for viewing the beam is the use of a remote camera system. Remote viewing, although expensive, virtually eliminates eye hazards associated with alignment procedures.

5. Enclosures, Beam Barriers, Beam Stops and Collimators

Whenever possible, enclose as much of the beam as possible without interfering with the application. Enclosures do not have to be sophisticated, but must contain the beam safely and be marked to indicate the presence of the beam inside the enclosure. By totally enclosing the beam, you may eliminate the need for other safety precautions. For example, you might effectively change a Class 4 laser system into a Class 1 system with proper enclosures and interlocks. Be careful not to use combustible enclosure materials with Class 4 laser systems.

Another effective and versatile tool for reducing the hazard from stray laser radiation is the use of beam barriers or beam curtains to surround all or part of the laser system or optical bench. Labyrinth designs can be used to limit the hazard while maintaining ready access to laser systems. Be sure the barrier materials will reduce the beam power below the MPE and do not use combustible barrier materials with Class 4 laser systems.

For exposed beam paths, appropriate beam stops must be used behind optical devices used to change the direction of the beam. The use of these stops will prevent the beam from leaving the table should the beam become misaligned. Again, do not use combustible beam stops with Class 4 laser systems.

Beam collimators or tubes can be useful in restricting the path of the beam should misalignment occur. Many optical devices have a metal ring surrounding the device that will act as a beam collimator. All optical supports, collimators, etc. should be surfaced, treated, or painted so as to reduce the potential for specular reflections.

6. Beam Condensation, Enlargement and Focusing

Manipulation of the beam diameter will change the hazard from intrabeam exposure. For example, beam enlargement will reduce the irradiance or radiant exposure level, but will increase the probability of scattering due to the enlarged cross section of the beam as it passes through optics.

A focused beam will present a greatly increased hazard at the focal point, but will expand quickly past the focal point, substantially reducing the irradiance or radiant exposure level (as compared to the initial beam).

7. Beam Filtration, Nonlinear Optics and Pumping Lasers

Beam power and other characteristics may be manipulated through the use of filtration devices. Do not rely on filters to reduce or eliminate beam hazards unless they are expressly designed for that purpose. Be aware that prolonged exposure to laser radiation may bleach filter devices, changing their absorption and their ability to reduce hazards.

Nonlinear optics used to manipulate the frequency of the incident laser radiation is now extremely common. The use of these optics may present multiple laser wavelengths on the optical bench top. All laser wavelengths must be considered when assessing hazards. The issue of multiple wavelengths also applies to the use of lasers to pump other lasers and amplifiers. Whenever possible, it is advisable to enclose unused beams (of differing wavelengths) to limit the number of laser hazards.

8. Preventing and Controlling Reflections

Any item placed in the beam path may result in a specular or diffuse reflection of the laser beam. For this reason, it is important to restrict the items on the optical bench to those intended to manipulate the beam path. Good housekeeping should not be overlooked as a source of laser hazard control. Tools, unused optical devices, and other items should not be left on the optical table.

For invisible beams, the nature of reflection and absorption at the particular wavelength should be considered in order to adequately control reflections on various surfaces.

C. Personal Protective Equipment

1. Laser Protective Eyewear

The exclusive use of laser protective eyewear has, in the past, often been stressed as the best method of eye safety in the laser laboratory. At MSU, laser protective eyewear is only one of many required laser safety control measures. In general, it is better to control laser hazards through the use of engineering controls (enclosures, beam blocks, etc.) and administrative controls (posting, procedures, etc.) rather than to rely solely on laser protective eyewear.

Laser protective eyewear is essential during the beam alignment process. Most laser accidents occur during beam alignments and these can be prevented by wearing the appropriate laser protective eyewear. The laser protective eyewear selected must allow proper viewing of the beam at or just below the MPE. Laser users commonly suffer eye injury when they remove their eyewear because they can not properly view the beam. NOTE: The intensity of a visible beam at the MPE is, by definition, sufficient to trigger the human aversion response. This means a diffuse reflection off a card is more than bright enough to view in a lighted room. The visible light transmission (VLT) of the laser protective eyewear must be sufficient (35% or more) to eliminate the need to remove the eyewear while working in the lighted laser facility. ORS recommends that the lights be kept on in the laser facility. Working in a darkened room will increase the potential hazard of eye injury by increasing the pupil size while increasing the need to remove the laser protective eyewear to be able to see.

All laser protective eyewear must be marked with the absorption wavelength and the optical density (OD) at that wavelength. It is recommended that laser protective eyewear be color coded to the laser of concern with colored tape. This can prevent mishaps when several lasers of different wavelengths are being used.

Selection of appropriate laser protective eyewear is very important. Several different laser protective eyewear styles are available depending on the needs of the user (see Appendix H). The laser protective eyewear selected must have the appropriate OD at the wavelength(s) of concern and must be comfortable enough to wear as required. Contact EH&S if you need additional information on laser protective eyewear.

2. Skin Protection

UV laser systems or UV excitation sources can present severe hazards to exposed skin surfaces. If the UV source cannot be enclosed to prevent scattered radiation exposure, it may be necessary to wear appropriate coverings to protect the skin. These coverings may include gloves, UV face shield, lab coat, etc.

D. Combined Control Methods

1. Invisible Beam Hazards

The use of invisible beams (UV or IR) presents unique hazards. Be sure that beam paths are clearly identified. For example, tape strips can be used for defining beam paths on optical tables. Have the appropriate viewing aids (such as fluorescent cards or IR viewers) available for use during alignment procedures.

NOTE: Particular caution should be exercised when viewing wavelengths that are at the borderline of the visible and near infrared. An example is the Ti-Sapphire laser at 800 nm. This beam (at full power) can be imaged in a dark room as a dull red spot on a card (usually without laser protective eyewear). This is very hazardous because the human eye is "seeing" the 800 nm wavelength at very poor relative efficiency (0.0001%) compared to yellow light (100% at 575 nm). The user can be fooled into thinking the power is low (what the user's eye is telling them) when the actual irradiance of the beam is very high. Many eye injuries have occurred during alignments with Ti-Sapphires. Wavelengths longer than 700 nm should be treated as infrared beams and laser protective eyewear should always be worn during alignments.

2. Repair and Maintenance Hazards

During repair or maintenance, access to laser radiation is more probable because of the removal of the laser housing. Only qualified persons should perform laser system maintenance or repair. The appropriate laser protective eyewear must be used during all alignments and whenever exposure to laser radiation is anticipated.

Vendor and service personnel working at MSU should follow the established MSU safety practices. It is the responsibility of the PI to inform these persons regarding the appropriate procedures. If the vendor has their own safety procedures, these should also be followed. In the event of conflict between the MSU Laser Safety Program and the vendor’s procedures, the EH&S should be consulted before work begins.

Section 6: Ancillary Hazards and Control Methods

A. Toxic Dye Hazards

B. Hazards from laser Generated Air Contaminants (LGAC)

C. Cryogen Hazards

D. Compressed Gas Hazards

E. High Voltage Power Hazards

F. Collateral Radiation Hazards

G. Fire and Explosion Hazards

H. Noise Hazards

A. Toxic Dye Hazards

The fluorescent dyes (used with dye lasers) can present substantial hazards due to their toxicity. Some of these dyes are suspected of being carcinogenic or mutagenic. The solvents used for mixing the dyes may be flammable, toxic, or present other health hazards. Material Safety Data Sheets (MSDS) on dyes or solvents are available from your department or by contacting EH&S.

Because the dyes normally come in a dry power form, they are readily dispersible and should be handled and mixed with great care. A lab coat, disposable gloves, safety glasses or goggles, and a properly functioning chemical fume hood must be used when handling or mixing the dyes. Good housekeeping should be maintained before, during, and after the mixing. Use double containment adequate to contain the entire volume of the dye solution when they are being mixed, stored, and used. Clean up any spills immediately using the appropriate protective equipment. Contact EH&S or its designee if you need additional information.

B. Hazards from Laser Generated Air Contaminants (LGAC)

The interaction of the laser beam with target materials may produce toxic dusts, vapors or gases called LGAC. This is particularly true during material processing (welding, cutting, vapor deposition, etc.). Toxic products resulting from laser processing must be properly controlled through the use of adequate ventilation and filtration. EH&S or its designee should be consulted whenever LGAC may result from the laser use.

C. Cryogen Hazards

Some lasers and laser systems may require the use of cryogenic liquids (liquid nitrogen, oxygen, hydrogen, etc.). These liquids present skin and eye hazards from their extremely low temperatures and should not be handled without insulated gloves, goggles and a face shield. The dewars used for transport and storage of cryogens may present implosion hazards if they are made of glass. Glass dewars should be carefully wrapped with strong tape to contain glass fragments should they implode.

If the cryogenic liquid is allowed to warm to room temperature, the resulting gas will expand to more than 600 times the volume in the liquid state. Once it expands to become a gas, the gas may present an additional hazard (toxic, asphixiant, etc.). The specific hazards of the cryogen can be found in the MSDS. Your department safety contact should be consulted whenever cryogenic liquids are being used.

D. Compressed Gas Hazards

The use of compressed gases is common in the laser laboratory. Some lasers use both pure gases or gas mixtures as the lasing media. The high pressure of the gas translates into substantial potential energy stored in the cylinder. If this pressure is released in an uncontrolled manner (such as broken nozzle) the cylinder can become an unguided missile. Compressed gas cylinders must be properly restrained to prevent damage to the nozzle or regulator.

The gases themselves may present a variety of hazards if they leak from the cylinder. Depending on the gas, it may be toxic, corrosive, flammable, etc. Again, refer to the MSDS for detailed information on the gas in question. If the hazards are sufficient, it may be necessary to provide a gas cabinet under negative pressure to control the hazard in the case of a leak. Inform your department safety contact if compressed gases are to be used in the laser facility.

E. High Voltage Power Hazards

The high voltage power supplies associated with laser systems have been responsible for serious injuries and electrocutions. For this reason, it is important to know the hazards associated with your laser and the laser's power supply. Capacitor systems are of particular concern because they can remain hazardous long after the main power is disconnected. Capacitor systems should be safely discharged several times with the main power off to reduce the hazard before beginning work.

Only qualified persons should perform high voltage laser or power supply maintenance or repair. As a precaution, a second person (knowledgeable in high voltage safety and CPR) should always be in attendance when high voltage work is being performed.

F. Collateral Radiation Hazards

Laser excitation systems and power supplies may produce hazardous collateral radiation of various types. These hazards are normally controlled by the equipment housings, and are usually a problem only if the protective housings are removed.

The laser excitation device may produce very intense UV/Visible/IR radiation that can be hazardous. Collateral ultraviolet radiation may injure both the eye and the skin if the exposure duration is long enough. Blue light presents a special hazard because of its ease of absorption in the retina. This "Blue Light Hazard" is thought to create photochemical injury in the retina. Exposure to any very intense visible light source can seriously degrade color vision and night vision capabilities (see Appendix F for additional information). Exposure to these intense light sources should be carefully controlled or eliminated by leaving the housings in place.

Laser power supplies capable of creating energies greater than 15 kVp may be a source of x-rays if they contain high voltage vacuum tubes. Electric discharge excitation sources in lasers may also be a source of x-rays. Generally, these x-rays are low energy and are shielded by the equipment housings.

G. Fire and Explosion Hazards

As mentioned before, Class 4 lasers can present fire hazards. Lasers being operated in a CW mode with a beam power that exceeds 0.5 Watt can ignite or cause off gassing in combustible materials left in the beam path. Beam stops, barriers, and curtains used with Class 4 lasers must be made of non-combustible materials. All Class 4 laser labs should have an ABC Type extinguisher readily available as a fire precaution. Laser users should receive fire prevention training.

Explosion hazards in the laser lab include: the storage and use of flammable solvents and gases (both compressed and cryogenic) and the implosion potential from dewars and excitation flash lamps. Proper storage and control of these sources should reduce the potential hazard.

H. Noise Hazards

Some laser systems create significant levels of noise in the laser laboratory. If the noise level seems unpleasant or painful, contact your department safety contact to have a noise survey done.

Section 7: Appendices

A. Training Certification Document
B. Laser Safety Guidelines
C. Laser Types and Wavelengths
D. ORS Laser Inspection Form
E. Eye Component Diagram
F. Bio-effects Chart
G. Glossary of Laser Terms
H. Types of Laser Protective Eyewear
I. Laser Protective Eyewear for Alignments
J. Laser Accident Case Studies

Appendix A

TRAINING CERTIFICATION DOCUMENT

Name of Laser User (print): ____

Name of Principal Investigator: ____

LUR Number: ________________ Phone No. _____________________________

Laboratory Location: ____

I have read and understand the MSU Laser Safety Training Supplement and Laser Use Registration and have received instruction from the Principal Investigator (or their designee) in the use of the laser system, associated optics, and laser safety systems. I am aware that I am responsible for following the established safety standards and laboratory SOP's and that I am responsible for my own safety in the laboratory.

Signed: __________________________________ Date: ______________________

Send the completed form to: EH&S

Appendix B

MSU LASER SAFETY GUIDELINES

Operation Guidelines

1) Intrabeam viewing of laser beams is not allowed on campus.

2) Never look directly into any laser beam for any reason.

3) Enclose the laser beam path whenever possible.

4) Use appropriate laser protective eyewear for all laser beam alignments.

5) Restrict unauthorized access to laser facilities.

6) Do not operate lasers at sitting or standing eye level.

7) Shield all laser light pumping sources.

8) Remove all reflective or combustible materials from the beam path.

9) Use diffuse (non-reflective) beam stops, barriers and enclosures.

10) Use low beam power (or an alignment laser) for alignments.

11) Remove all keys from interlocks when the laser is not in operation.

12) Alert persons in the area when the beam is operating.

13) Be aware of and protect users from all non-beam hazards.

14) Never override any laser system safety interlock.

Administration Guidelines

1) Mark all laser facility entrances with an ANSI laser hazard sign.

2) Complete, sign, and return a laser safety-training certificate to EH&S.

3) Report all accidents or suspected eye injuries to EH&S.

4) Eye exams may be required for Class 3b and 4 laser users.

5) Inform EH&S or its designee of any transfer or sale of lasers.

6) Laser facilities are inspected periodically by EH&S or its designee.

7) Inform EH&S or its designee of any new, modified or relocated lasers.

8) Call EH&S at 4367 any time you need laser safety assistance.

Appendix C
LASER TYPES AND WAVELENGTHS

LASER MEDIA	WAVELENGTH (nm)
(ULTRAVIOLET)	(100 nm - 400 nm)
Fluorine (diatomic gas excimer)	157
Argon Fluoride (excimer)	193
Krypton Chloride (excimer)	222
Krypton Fluoride (excimer)	248
Xenon Chloride (excimer)	308
Helium Cadmium	325/354
Nitrogen	337.1
Krypton	351/356
Xenon Fluoride (excimer)	351
Argon	351/364
(VISIBLE)	(400 nm - 700 nm)
Helium Cadmium (blue)	442
Argon (blue)	458
Helium Selenium (tunable)	460 - 1260
Krypton (blue)	476
Argon (blue)	477
Argon (blue)	488
Rhodamine 6G (tunable dye)	500 - 650
Copper Vapor (green)	511
Argon (green)	515
Krypton (green)	531
Manganese Vapor (green)	534/1290
Helium Neon (green)	544
Erbium: YLF (green)	551
Krypton (yellow)	568
Copper Vapor (yellow)	578
Helium Neon (yellow)	594
Helium Neon (orange)	612
Gold Vapor (red)	628/312
Helium Neon (red)	633
Krypton (red)	647
Gallium Aluminum Arsenide (red diode)	670
Titanium Sapphire (tunable)	670 - 1130
Krypton (red)	676
Ruby (red)	694
(NEAR INFRARED)	(700 nm - 1400 nm)
Alexandrite (tunable)	700 - 815
Lead Vapor	723
Krypton	753
Chromium: LiSAF (tunable)	780 - 1010
Gallium Aluminum Arsenide (diode)	840
Calcium Vapor	852/866
Gallium Arsenide (diode)	905
Neodymium: YAG	1064/1320
Barium Vapor	1130/1500
Helium Neon	1152/3390
(FAR INFRARED)	(1400 nm - 1 mm)
Erbium: Glass	1540
Holmium: YLF	2060
Thulium: YAG	2010
Holmium: YAG	2100
Erbium: YAG	2490
Erbium: YSGG	2790
Hydrogen Fluoride	4000 - 6000
Carbon Monoxide	5000 - 5500
Carbon Dioxide	9.6/10.6 (um)
Water Vapor	118 (um)
Hydrogen Cyanide	337 (um)

Appendix D

LASER INSPECTION FORM

Surveyors Name: ___________________________________ Date of Inspection: ______________________
Location of Laser System(s): ____
Name of PI: _____________________________ Phone #: _______________________
Name of Lab Contact: _____________________ Phone #: _______________________
Applicable LURs: __________________________________

Laser Posting, Labeling and Security Measures
Entrances properly posted: Y N Comments:____
Room security adequate: Y N Comments: ____
Door interlock system: Y N Comments: ____
Interlock functioning: Y N Comments: ____
Laser status indicator outside room: Y N Comments:____
Laser class label in place: Y N Comments: ____
Laser aperture label in place: Y N Comments: ____

Laser Unit Safety Controls
Protective housing in place: Y N Comments: ____
Interlock on housing: Y N Comments: ____
Interlock on housing functioning: Y N Comments: ____
Beam shutter present: Y N Comments: ____
Key operation: Y N Comments: ____
Laser activation indicator on console: Y N Comments: ____
Beam power meter: Y N Comments: ____
Emergency shutoff available: Y N Comments: ____

Engineering Safety Controls
Laser secured to table: Y N Comments: ____
Laser optics secreted to prevent stray beams: Y N Comments: ___________________________________
Laser not at eye level: Y N Comments: ____
Beam is enclosed: Y N Comments: ____
Beam barriers in place: Y N Comments: ____
Beam stops in place: Y N Comments: ____
Remote viewing of beam: Y N Comments: ____
Beam condensed or enlarged: Y N Comments: ____
Beam focused: Y N Comments: ____
Beam intensity reduced through filtration: Y N Comments: _______________________________________
Fiber optics used: Y N Comments: ____
Windows in room covered: Y N Comments: ____
Reflective materials kept out of beam path: Y N Comments: _____________________________________
Laser user checking for stray beams: Y N Comments: ____
Physical evidence of stray beams: Y N Comments: ____
Class 4 diffuse reflection hazard: Y N Comments: ____

ADMINISTRATIVE SAFETY CONTROLS:
LUR up-to-date: Y N Comments: ______
LUR posted: Y N Comments: ______
SOP up-to-date: Y N Comments: ______
SOP posted: Y N Comments: ______
Emergency contact list posted: Y N Comments: ______
Laser safety guidelines posted: Y N Comments: ______
Laser safety policy manual available: Y N Comments: ______
Laser safety training supplement available: Y N Comments: ______
All users have met laser safety training requirement: Y N Comments: ______

OTHER LASER SAFETY MEASURES:
Laser eye exam requirement met: Y N Comments: ______
Proper laser eye protection available: Y N NA Comments: ______
Proper skin protection available: Y N NA Comments: ______

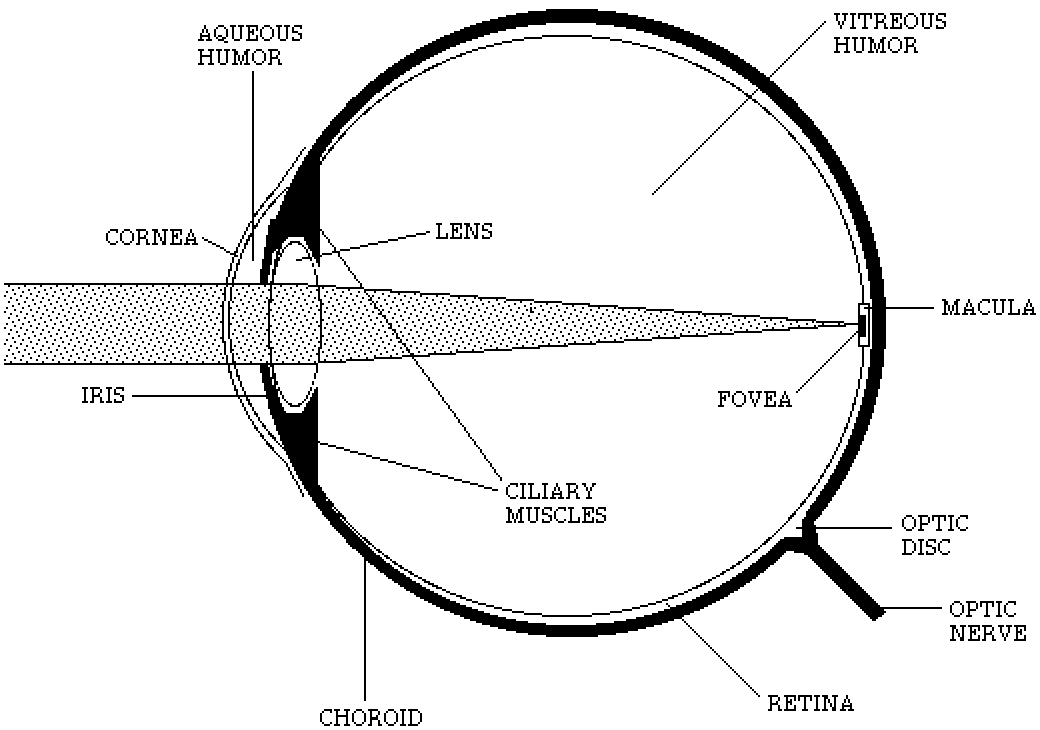
NON BEAM HAZARDS:
Toxic laser media in use: Y N Comments: ______
Hazardous laser media stored properly: Y N Comments: ______
Fume hood for dye mixing: Y N NA Comments: ______
Cryogens in use: Y N Comments: ______
Compressed gas in use: Y N Comments: ______
Gas cylinders restrained: Y N Comments: ______
All V belts, pulleys, and fans adequately guarded: Y N Comments: ______
High voltage power hazard: Y N Comments: ______
Electrical panels are unobstructed: Y N Comments: ______
Optical tables properly grounded: Y N Comments: ______
Collateral radiation hazard: Y N Comments: ______
Explosion hazard: Y N Comments: ______
Fire hazard: Y N Comments: ______
LGAC production: Y N Comments: ______

ADDITIONAL COMMENTS:
______
______
______
______
______
______
______

LASER CONFIGURATION DIAGRAM ATTACHED

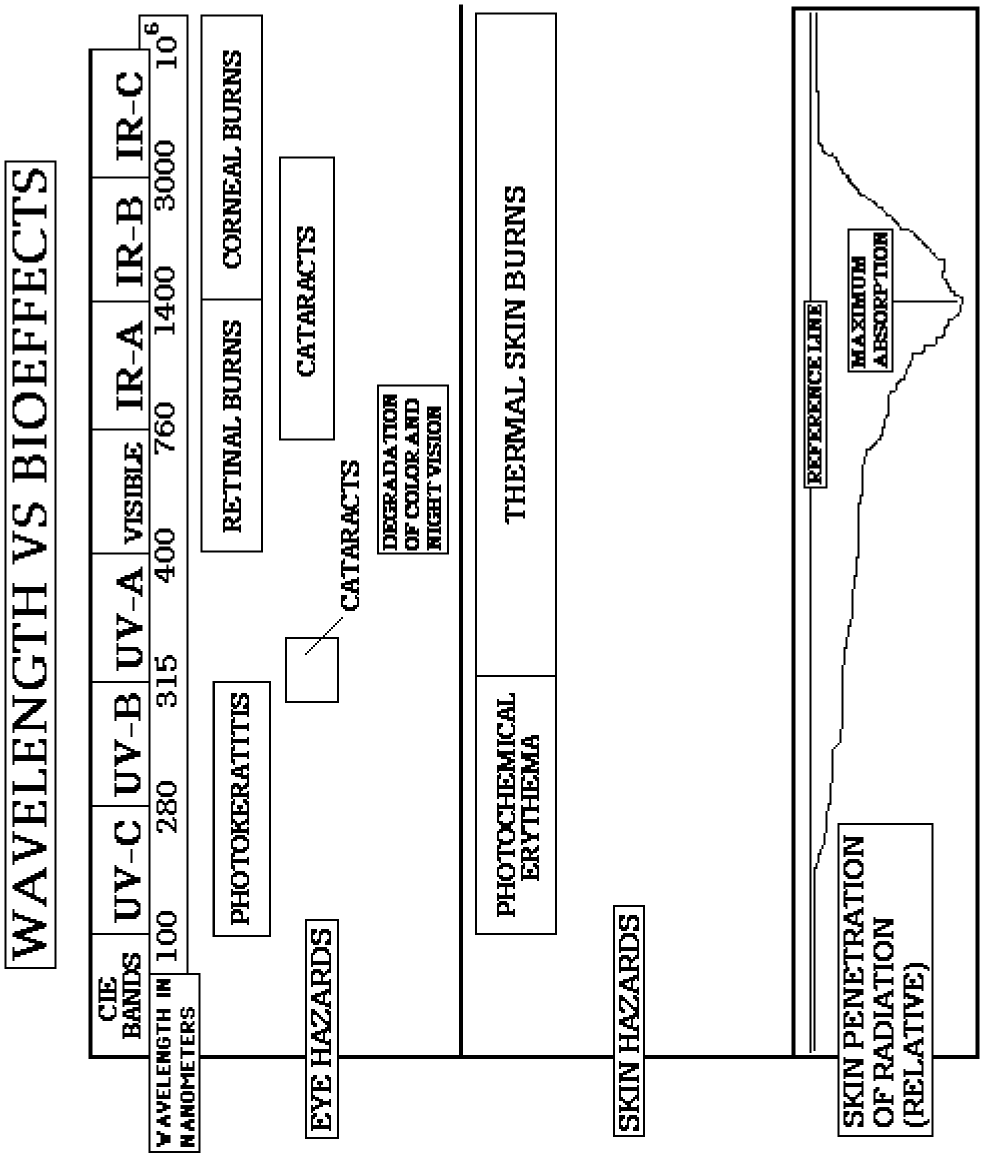
Appendix E

EYE COMPONENT DIAGRAM



NOTE: The diagram shows a laser beam entering the eye and being focused on the fovea. If the beam power is sufficient, this situation could cause blindness

Appendix F
Bio-effects Chart



Appendix G

Glossary of Laser Terms

Accessible exposure limit (AEL) - The maximum allowed power within a given laser classification.

American National Standards Institute (ANSI) - The technical body which releases the Z136.1 Standard for the Safe Use of Lasers. The secretariat for the Z136.X standard series is the Laser Institute of America (LIA).

Average power - The average power of a pulsed laser is the product of the energy per pulse (J/pulse) and the pulse repetition frequency (Hz or pulses/sec). The average power is expressed in Watts (J/sec).

Coherent radiation - Radiation whose waves are in-phase. Laser radiation is coherent and therefore very intense.

Continuous wave (CW) - A term describing a laser that produces a continuous laser beam while it is operating (verses a pulsed laser beam).

Diffuse reflection - When an incident radiation beam is scattered in many directions, reducing its intensity. A diffusely reflecting surface will have irregularities larger than the wavelength of the incident radiation beam. See specular reflection.

Intrabeam exposure - Exposure involving direct on-axis viewing of the laser beam. Looking into the laser beam would constitute intrabeam exposure. NOTE: Intrabeam viewing of lasers is not permitted on campus.

Infrared (IR) radiation - Invisible radiation with a wavelength between 780 nm and 1 mm. The near infrared (IR-A) is the 780 to 1400 nm band, the mid infrared (IR-B) is the 1400 to 3000 nm band, and the far infrared (IR-C) is the 3000 nm to 1 mm band.

Irradiance - The power being delivered over the area of the laser beam. Also called power density, irradiance applies to CW lasers and is expressed in W/cm2.

Laser - **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation. A monochromatic, coherent beam of radiation not normally believed to exist in nature.

Laser user - Any person who uses a laser for any purpose on the MSU campus.

Laser Safety Manual - A document defining the MSU Laser Safety Program. Copies are available from EH&S.

Laser Use Registration (LUR) - The mechanism used by EH&S to track lasers on campus. The LUR details the safety requirements for each Class 3a, 3b, and 4 laser.

Maximum permissible exposure (MPE) - The maximum level of radiation which human tissue may be exposed to without harmful effect. MPE values may be found in the ANSI Z136.1 Standard.

Material Safety Data Sheet (MSDS) - A document, required by law, which is supplied by the manufacturer of a chemical. The MSDS details the hazards and protective practices required for protection from those hazards, as well as other information.

Nominal hazard zone (NHZ) - The area surrounding an operating laser where access to direct, scattered or reflected radiation exceeds the MPE.

Optical density (OD) - Also called transmission density, the optical density is the base ten logarithm of the reciprocal of the transmittance (an OD of 2 = 1% transmittance).

Office of Environmental Health & Safety (EH&S) – The department responsible for the implementation of the Laser Safety Program.

Peak power - The highest instantaneous power level in a pulse. The peak power is a function of the pulse duration. The shorter the pulse, the greater the peak power.

Principal investigator (PI) - The person directly responsible for the laser and its use. The PI has direct responsibility for all aspects of safety associated with his/her research and/or teaching.

Radiant exposure - The energy being delivered over the area of the laser beam. Also called energy density, radiant exposure applies to pulsed lasers and is expressed in J/cm2.

Specular reflection - Results when an incident radiation beam is reflected off a surface whose irregularities are smaller than the radiation wavelength. Specular reflections generally retain most of the power present in the incident beam. Exposure to specular reflections of laser beams is similar to intrabeam exposure. See diffuse reflection and intrabeam exposure.

Standard operating procedure (SOP) - A procedure that explains a standard procedure or practice. For lasers, SOPs usually deal with alignment procedures.

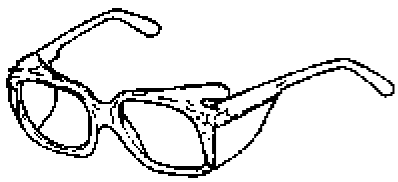
Ultraviolet (UV) radiation - Invisible radiation with a wavelength between 10 nm and 400 nm. The near ultraviolet (UV-A) is the 315 to 400 nm band, the mid ultraviolet (UV-B) is the 280 to 315 nm band, the far ultraviolet (UV-C) is the 100 nm to 280 nm band, and the extreme ultraviolet is the 10 to 100 nm band. Note: Wavelengths below 200 nm are absorbed in the atmosphere and are known as the vacuum ultraviolet.

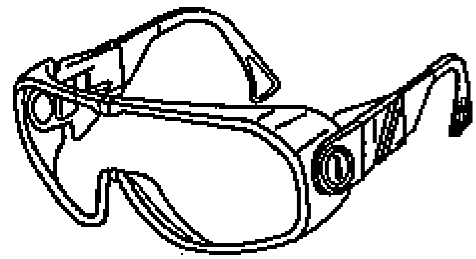
Visible Light - Radiation that can be detected by the human eye. These wavelengths are between 400 and 780 nm. The colors (with approximate wavelengths) are: Violet (400 - 440 nm), Blue (440 - 495 nm), Green (495 - 545 nm), Yellow (545 - 575 nm), Orange (575 - 605 nm), and Red (605 - 780 nm).

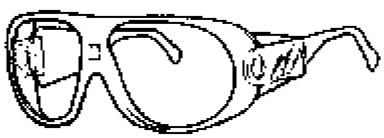
Appendix H

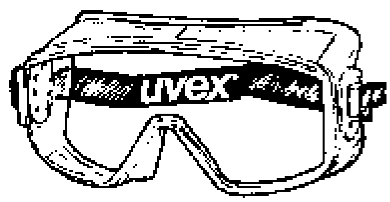
Types of Laser Protective Eyewear

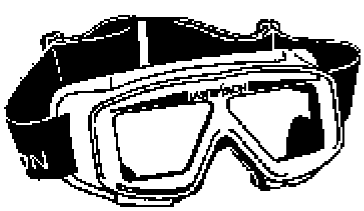
Here are some examples:

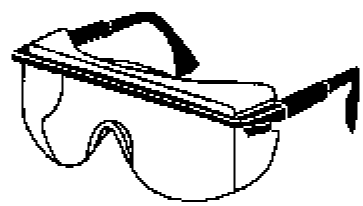












Appendix I

Laser Protective Eyewear for Alignments

Even if you are wearing laser protective eyewear, **never look directly into any laser beam.** Intrabeam viewing of lasers is not allowed except with the direct permission of EH&S or its designee. Contact EH&S if you feel that aligning your laser requires intrabeam viewing.

- The LUR document for each laser indicates if laser protective eyewear is required for alignment or use of the laser. If laser protective eyewear is required, the LUR specifies the OD (optical density) at the laser wavelength(s) being used. The OD specified is the minimum OD sufficient to protect the user against a momentary intrabeam or specular reflection exposure.

- For visible lasers, the minimum OD required to protect the user against intrabeam viewing should allow the viewing of a diffuse spot on a light colored surface. If the laser protective eyewear has an OD much larger than the specified minimum OD, it may be impossible to properly view a diffuse beam spot (or even see properly in the laser facility).

- In some instances (visible lasers from 400 - 450 nm and 650 - 700 nm), it may be preferable to reduce the OD below the specified intrabeam minimum OD to better view a diffuse spot. Reducing the OD by 1 or 2 should substantially improve viewing while still offering adequate eye protection (the intrabeam OD has a X10 safety margin calculated into the value which includes the human aversion (blink) response). Reducing the specified OD by a number greater than 2 may reduce the protection factor enough to allow eye injury should a specular reflection be viewed accidentally.

- For invisible lasers, the minimum OD for intrabeam viewing should not be reduced, as OD reduction will not aid in viewing the beam. Instead, the laser protective eyewear should be chosen to allow the wavelength produced by the viewing aid to be transmitted while absorbing the invisible beam. For example: a Nd:YAG beam at 1064 nm is being aligned with the use of an IR sensing card which absorbs some of the 1064 nm radiation and emits radiation at 550 nm. The calculated intrabeam OD for the Nd:YAG is 6.0. A good choice for laser protective eyewear would be a goggle with a UVEX type 06 filter (an OD of 8+ at 1064 nm and an OD of less than 1 at 400 to 700 nm). This goggle has a visible light transmission of 70% and should allow the diffuse spot to be easily viewed while giving excellent protection from the invisible Nd:YAG beam. NOTE: this eyewear would obviously not be a good choice if the Nd:YAG beam was frequency doubled to 532 nm.

- All laser protective eyewear should have a visible light transmission (VLT) sufficient to allow safe operation in the laser facility. EH&S recommends a VLT of at least 35%. Laser protective eyewear with a low VLT will generally not be worn by users and so cannot provide any protection.

Appendix J
Laser Accident Case Studies

LASER SYSTEM STANDARD OPERATING PROCEDURE (SOP) GUIDELINES

1. BASIC GUIDANCE

a. The written SOP must discuss beam alignment and normal operation for each laser system. It is advisable to include non-beam hazard management and servicing in the SOP.

b. To insure the SOP is read and used, the document should not be lengthy.

c. The primary intent of the SOP is to institutionalize good safety practices.

d. The Laser Use Registration, Laser Safety Manual, and Laser Safety Training Supplement have information that may be useful in developing the SOP.

e. The Office of Environmental Health & Safety will be happy to review and comment on the draft SOP. If you need help contact EH&S at 4367.

2. BEAM ALIGNMENTS (ADDRESS THESE SAFETY AREAS IN THE SOP)

a. SECURITY - Secure the lab and (to avoid distractions) mark the door with the following sign: "NOTICE - Laser Alignment in Progress - DO NOT ENTER - EYE PROTECTION REQUIRED."

b. PREPARATION - Locate all equipment and materials needed to perform the alignment prior to beginning the procedure.

c. BEAM CHARACTERISTICS - Is the beam visible or invisible? Is special equipment needed to view the beam? If the beam is pulsed, can you fire a single pulse at a time to limit the exposure hazard?

d. BEAM VIEWING - Intrabeam viewing is prohibited on the campus and a remote viewing camera should be used if intrabeam viewing is required to align the beam. Only diffuse reflections should be viewed directly. Use a low power alignment laser (Class 2 or 3a) or if none is available; always use the lowest beam power that will allow viewing of an image with protective eyewear.

e. PERSONAL PROTECTIVE EQUIPMENT - Use laser protective eyewear with a low enough OD to allow viewing of the diffuse reflection (contact ORS if you need information on alignment eyewear). Use skin covers (lab coat, gloves, and UV face shield) to protect users from UV laser beam scatter.

f. PERSONNEL - Whenever possible, the "buddy" system should be used during alignments. If another person is not available to be in the room, let someone else know where you are and check in with them on a regular basis.

g. EXPOSURE PRECAUTIONS - Keep the optical table clear of objects that may cause unwanted specular reflections. Always close the laser shutter while adjusting optics or when entering the beam path. After making adjustments, assure the optics are secured prior to opening the shutter.

h. REPLACE BEAM CONTROLS - Insure all beam blocks, enclosures, and beam barriers are replaced when the alignment is complete.

i. CHECK DOOR SIGNS - Verify that the "NOTICE - Laser Alignment in Progress - DO NOT ENTER - EYE PROTECTION REQUIRED" sign is removed from the room entrance and that the regular ANSI laser warning sign is in place and correct.

3. NORMAL OPERATION OF THE LASER (ADDRESS THESE SAFETY AREAS IN THE SOP)

a. SECURITY - Do not rely upon a closed door as adequate security. Always use key locks or activate the door interlocks (if required by the LUR) on the laser facility.

b. OPERATIONAL PREPARATIONS - Indicate the location of the Laser Safety Guidelines posting. Indicate the equipment needed to perform the (laboratory specific) experiment.

c. PERSONAL PROTECTIVE EQUIPMENT - Have the appropriate (laboratory specific) safety equipment on hand. Specify what is needed and it's use.

d. START-UP PROCEDURE - Insert key, turn on water, turn on power supply, close shutter, activate laser, etc. as specific to the laboratory.

e. EXPERIMENTAL PROCEDURE - Specific to the laboratory.

f. EMERGENCY PROCEDURE - Location of "PANIC" shut-down switch. Location of emergency procedure posting. Location of fire extinguisher, safety shower, etc.

g. SHUT-DOWN PROCEDURE - Specific to the laboratory.

h. STORAGE - Remove and store laser activation key, deactivate interlocks (if applicable) and secure door to laser facility.

4. NON-BEAM HAZARDS TO ADDRESS

a. TOXICITY OF LASING MEDIA - Toxic laser dyes should be handled with lab coat, safety glasses, and gloves. Dyes should be mixed in a properly functioning fume hood and transported in sealed, leak proof containers. Dye pumps should sit in a secondary containment tray. Concentrated halogen gases (greater than 5%) should be used and stored in a properly functioning gas cabinet.

b. ELECTRICAL HAZARDS - Only properly trained and PI approved personnel should work on high voltage systems. The "buddy" system should always be used when working on electrical systems and laboratory staff should be trained in CPR as a safety precaution.

c. COMPRESSED GASES - Staff should be trained in the safe management of cylinders and the hazards associated with the specific compressed gases being used.

d. FIRE PROTECTION - Attention should be given to protection against fires and explosions. Flammable solvents are often used for laser dyes and to clean optical components. Fire extinguishers should be well marked and staff should know how to use extinguishers and the fire alarm system.

e. HOUSEKEEPING - Poor housekeeping (on and off the bench) can create physical hazards. Staff may trip over cables that have not been secured and injuries may result from sharp tools that are not properly stored.

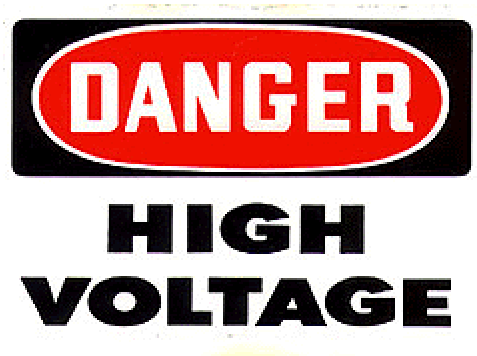
5. SAFETY ASSOCIATED WITH SERVICING OF THE LASER

a. Only PI approved and properly trained personnel should service laser systems. Vendor service staff are required to follow the vendor's laser safety policy. If MSU staff are assisting the service staff, the MSU staff must follow campus laser safety policy (eye protection, etc.).

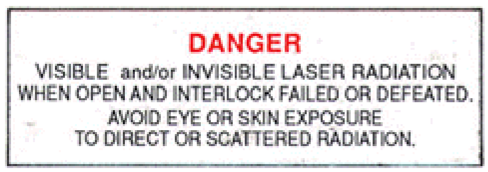
b. If MSU staff are to perform the service, a written service procedure with safe practice information must be available for reference (often the manufacturer will supply this information). All enclosures, interlocks, and safety devices (shutters, etc.) must be replaced and verified operational prior to returning the laser to service.

c. Safety interlocks shall not be permanently disabled without the consent of EH&S or its designee.

Laser Safety Signs & Labels

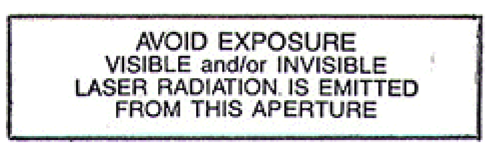


Sticker to mark high voltage hazard power supplies and laser enclosures.

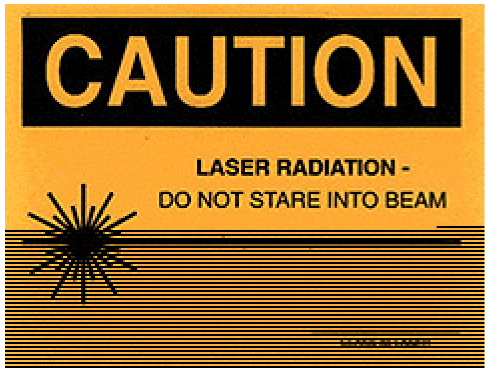


Sticker to mark laser enclosures.

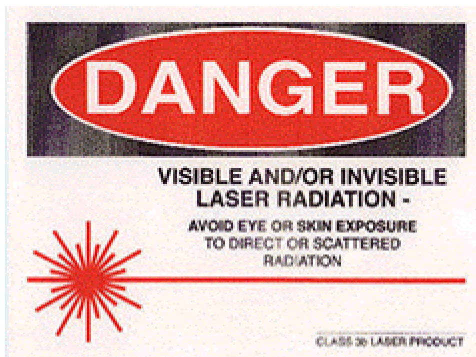
ANSI sign to mark doors to laser labs with Class 4 lasers.



Sticker to mark apertures where laser light is emitted.



ANSI sign to mark doors to laser labs with Class 3a lasers.



ANSI sign to mark doors to laser labs with Class 3b lasers.

Door sign to indicate laser alignment/maintenance.

<u>Laser Use Registration (LUR) Program</u>

The LUR Program

All Class 3a, 3b, and 4 lasers on the MSU campus are required to be operated under a campus Laser Use Registration or LUR. Use of a Class 3a, 3b, or 4 laser or laser system without an approved LUR is a violation of campus safety policy.

NOTE: Laser pointers, Class 1, and Class 2 lasers are exempt from this requirement.

NOTE: This requirement applies to all laser uses on campus, not just those being used in research.

Obtaining an LUR

To obtain an LUR, please contact EH&S by phone at 4367. EH&S will prepare an LUR document and inform the LUR holder of the safety requirements under the specific LUR.

LUR Specifics

The LUR holder (usually the Principal Investigator) is responsible for compliance with all safety precautions spelled out in both the specific LUR and the campus Laser Safety Program. Generally, an LUR is assigned for each laser in a facility. LUR facilities are surveyed on a periodic basis by staff from the Office of Environmental Health & Safety or its designee. Survey reports are sent to the LUR holder to inform him/her of any items that need correction. EH&S or its designee is available to provide laser safety assistance to the LUR holder upon request.

The LUR holder is responsible for informing EH&S or its designee of any changes in laser users operating under the LUR. He/she is also responsible for assuring the laser users submit laser safety training certificates to EH&S and that they receive laser eye exams (if required under the LUR).

The LUR holder is also responsible for informing EH&S or its designee of any changes in laser use, laser location, or laser transfer (inside or off campus).

For additional information on the LUR Program and on LUR holder responsibilities, see the campus Laser Safety Manual.

Emergency Procedure for Laser Accidents

(Emergency Contact Listing)

In the event of a laser accident do the following:

1) Shut down the laser system.
2) Provide for the safety of personnel (first aid, evacuation, etc.) as needed.

NOTE: If a laser eye injury is suspected, have the injured person keep their head upright and still to restrict any bleeding in the eye. Laser eye injuries should be evaluated by a physician as soon as possible.

3) Obtain medical assistance for anyone who may be injured.

MSU Police	5222
MSU Dept. of EH&S	4367

4) If there is a fire, leave the area, pull the fire alarm, and contact the POLICE department by calling 5222. Do not fight the fire unless it is very small and you have been trained in fire fighting techniques.
5) Inform the Office of Environmental Health & Safety as soon as possible.
After normal working hours, call the MSU Police Department ext. 5222
has reviewed the incident.
6) After an accident, do not resume use of the laser system until EH&S or its designee has reviewed the accident

Safety with Laser Dyes

Overview

Due to their usefulness, many laser laboratories use various laser dyes. Most of these dyes come in a solid power form that must be dissolved in solvents prior to use in the laser system. Improper use of dyes or solvents may present a range of hazards for the laser researcher.

Dye Hazards

Although little is known about them, many organic laser dyes are believed to be toxic and/or mutagenic. Because they are solid powders, they can easily become airborne and possibly inhaled and/or ingested. When mixed with certain solvents (DMSO), they can be absorbed through unprotected skin. Direct contact with dyes and with dye/solvent solutions should always be avoided.

Solvent Hazards

A wide variety of solvents are used to dissolve laser dyes. Some of these (alcohols) are highly flammable and must be kept away from ignition sources. Fires and explosions resulting from improper grounding or overheated bearings in dye pumps are not uncommon in laser laboratories. Dye pumps should be inspected, maintained, and tested on a regular basis to avoid these problems. Additionally, dye lasers should never be left running unattended. Some of the solvents used with laser dyes may also be skin irritants, narcotics, or toxics. You should refer to the Material Safety Data Sheet (MSDS) which is supplied by the solvent manufacturer for additional information on health effects.

Dye/Solvent Handling

Powered laser dyes should never be handled where the airborne dust could be breathed. Dyes must be mixed only in a properly functioning fume hood. The proper protective equipment (PPE = safety glasses, chemical gloves, and lab coat) should always be used by the person handling the dye. The gloves being used should be resistant to the solvent being handled. Mixing of dyes and solvents should be done carefully, so as to avoid spilling. Any spills or leaks should be cleaned up immediately using appropriate PPE. Avoid breathing fumes from the solvent being used. Clearly identify and mark containers used for mixed dye/solvent solutions. Practice good hygiene and wash your hands well after handling dyes.

Storage/Use of Mixed Dye/Solvent

Limit the amount of mixed dye/solvent being stored in the laboratory. Once mixed, the dye/solvent should be stored in sealed Nalgene or other unbreakable plastic containers (beware of solvent incompatibility) until ready to use. Be sure to check transfer lines and pump connections for continuity prior to each use with the dye/solvent. All pumps and dye reservoirs must be placed in trays with sufficient capacity to contain all of the dye/solvent should it leak. This "double containment" method should prevent dye stains on floors and other surfaces.

Dye Waste Disposal

Dyes and dye/solvent solutions are considered hazardous wastes and must be disposed of properly.