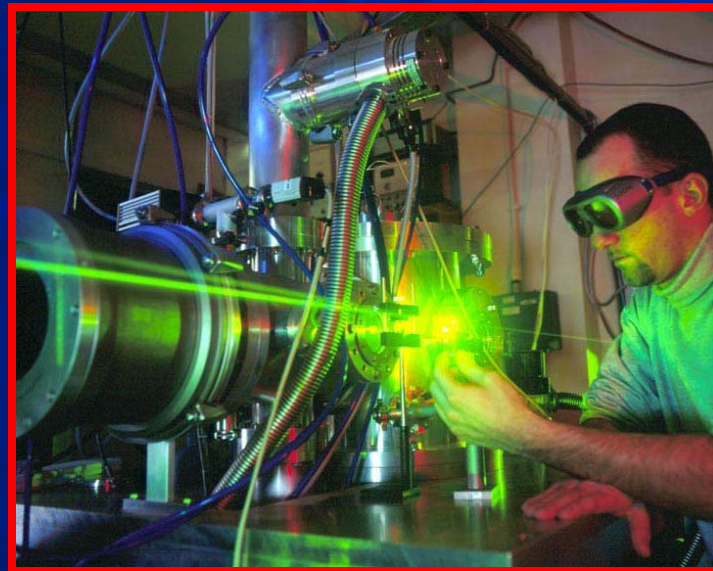


# Basic Laser Safety

**Boston University**

**Office of Medical Physics  
and Radiation Safety**



# Agenda

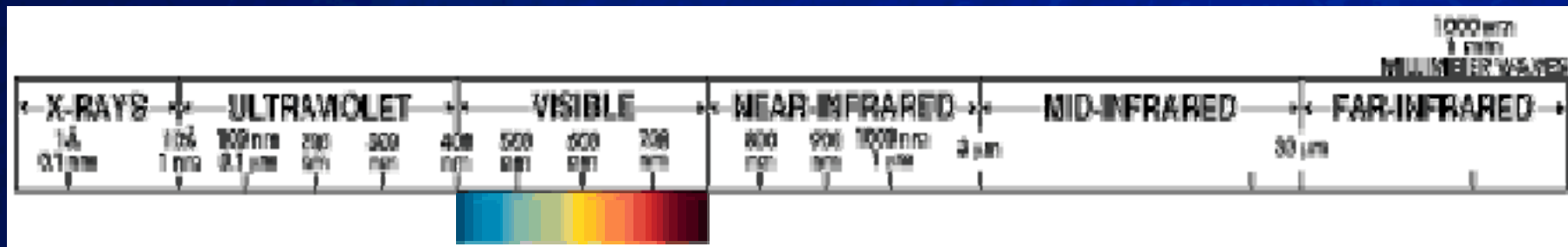
1. Introduction
2. Bioeffects
3. Hazards
4. Hazard Classes
5. Facility Requirements
6. Program Requirements
7. Laser Permit Application
8. Laser Safety Exercise

# Introduction

# Definition

- What is a Laser?
  - Light **A**mplification by **S**timulated **E**mission of **R**adiation
  - The energy generated by a laser is in or near the optical portion of the electromagnetic spectrum

# Electro-Magnetic Spectrum



## The optical spectrum.

Laser light is nonionizing and ranges from the:

- ultra-violet (100 - 400nm)
- visible (400 - 700nm), and
- infrared (700nm - 1mm).

# Laser Light

- Laser light is:
  - Monochromatic
  - Directional
  - Coherent
- Lasers pose more hazard than ordinary light because they focus energy onto a small area

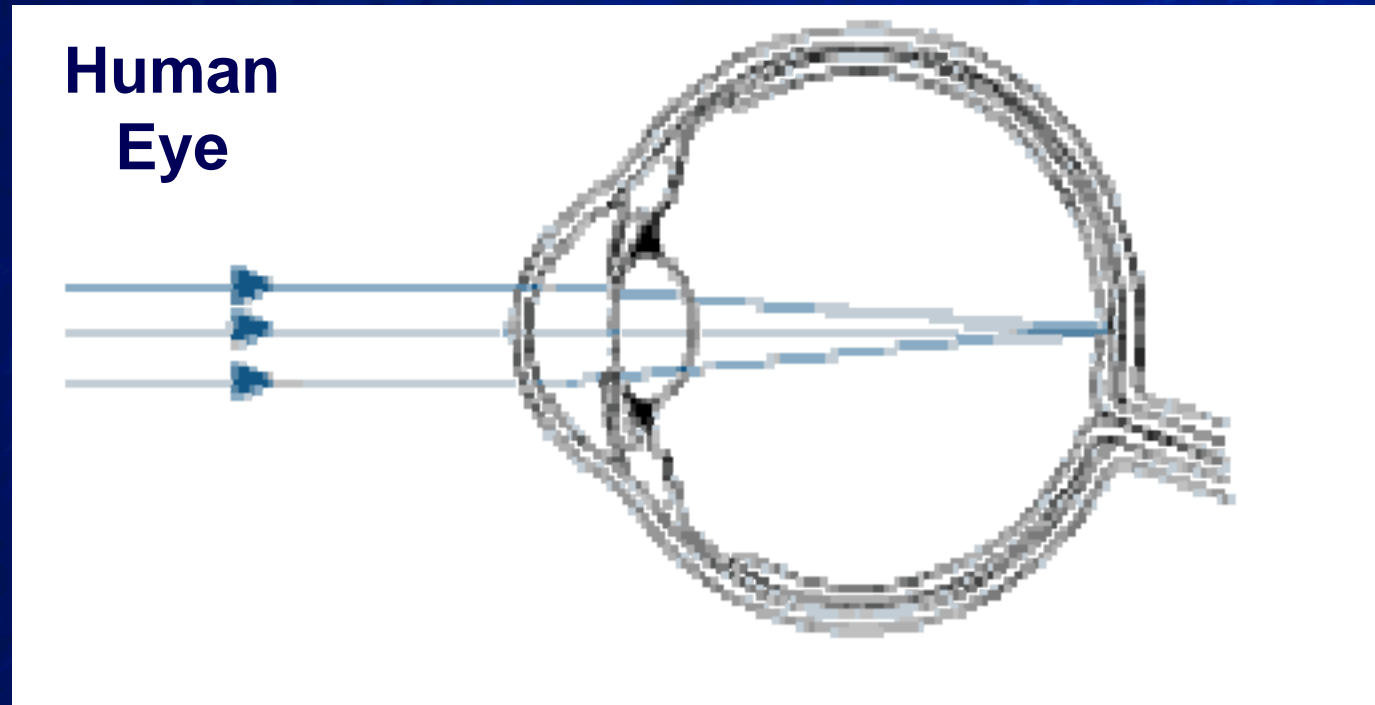
# Bioeffects

# Bioeffects

- Primary sites of damage
  - eyes
  - skin
- Laser damage can be:
  - Thermal
  - Acoustic
  - Photochemical



# Optical Gain



For wavelengths that focus on the retina (400-1400nm) the optical gain of the eye is about 100,000 times. If the irradiance entering the eye is  $1\text{mw}/\text{cm}^2$ , then the irradiance at the retina will be  $100\text{W}/\text{cm}^2$

# Bioeffects of IR-B, IR-C and Mid UV

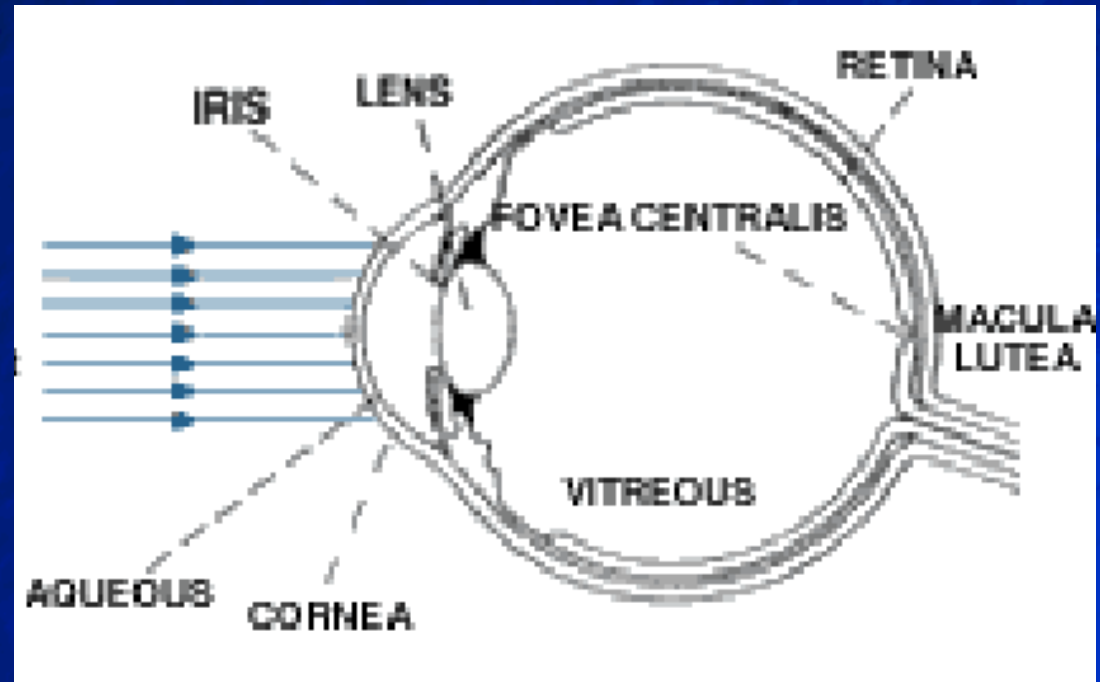
Mid-infrared and  
Far Infrared

(IR-B and IR-C)

1400nm-1mm

and Middle  
Ultraviolet

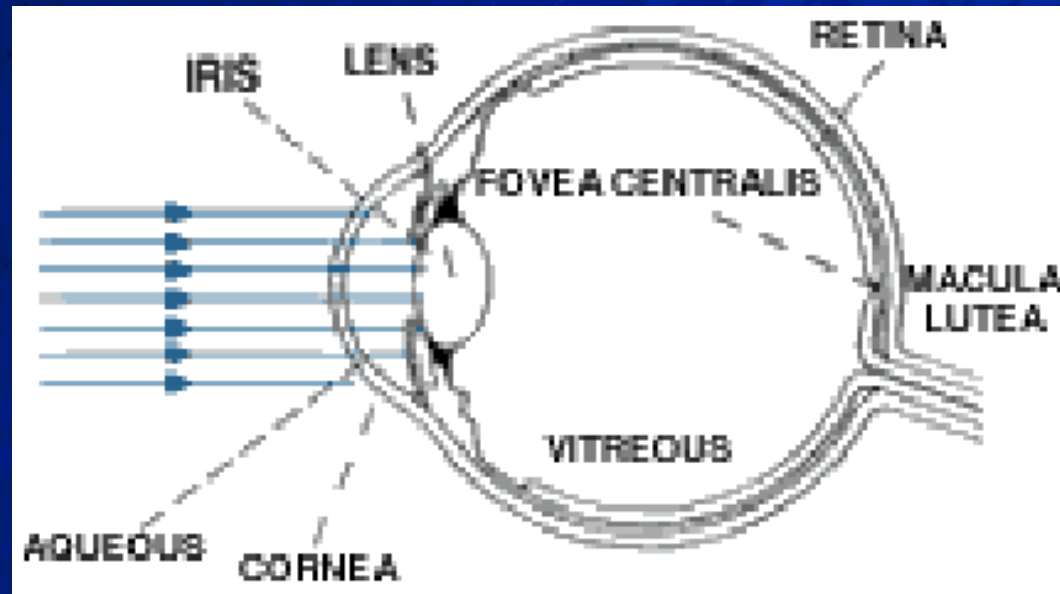
180nm - 315nm



# Bioeffects of Near UV

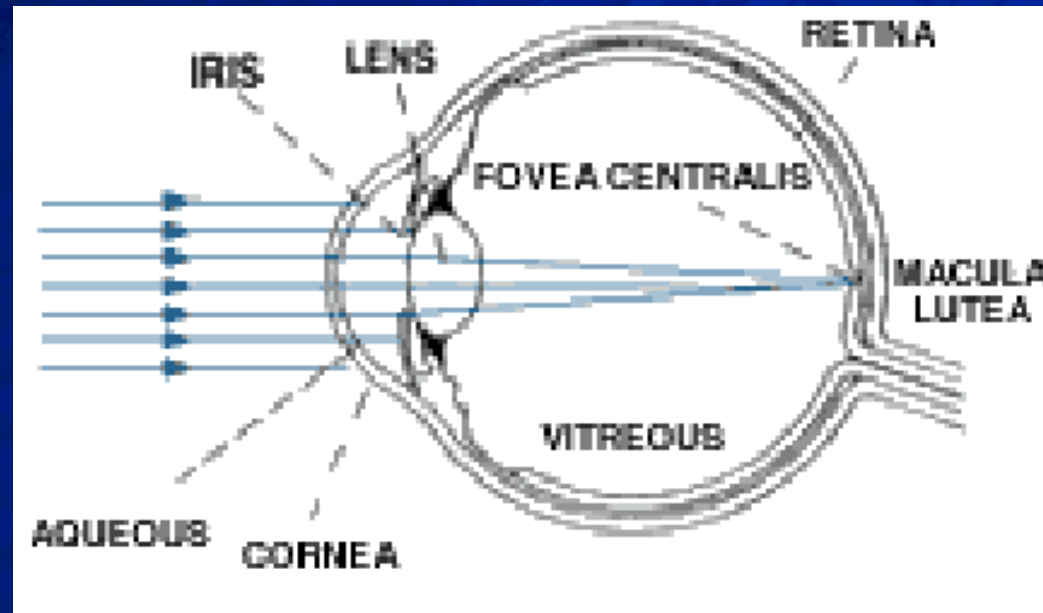
Near Ultraviolet  
(UV-A)

315-390nm



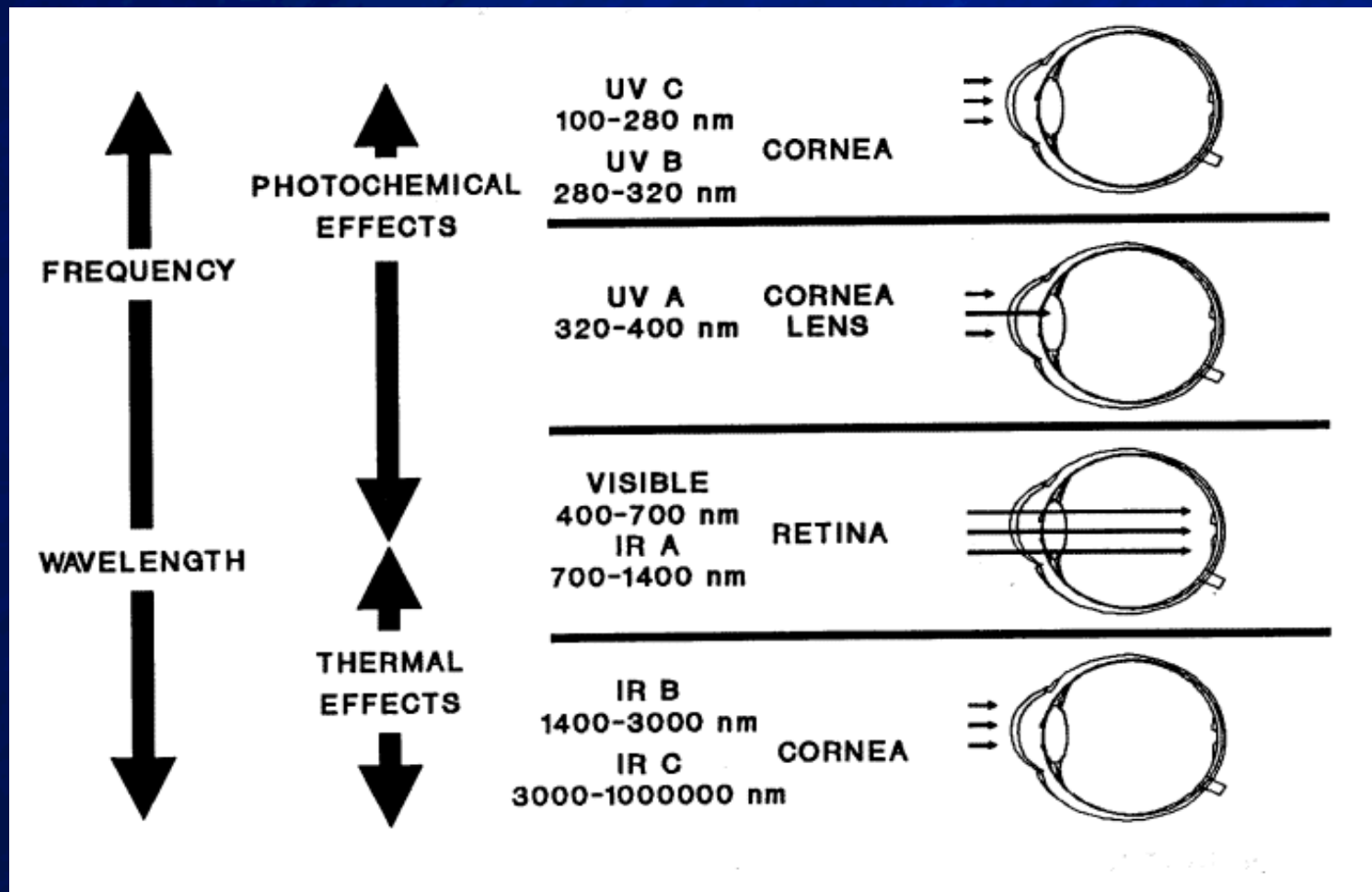
# Bioeffects of Visible and IR-A

Visible and  
Near-infrared  
(IR-A)  
400-1400nm



# First Law of Photobiology

Structure must absorb light to have an effect on it



# Hazards

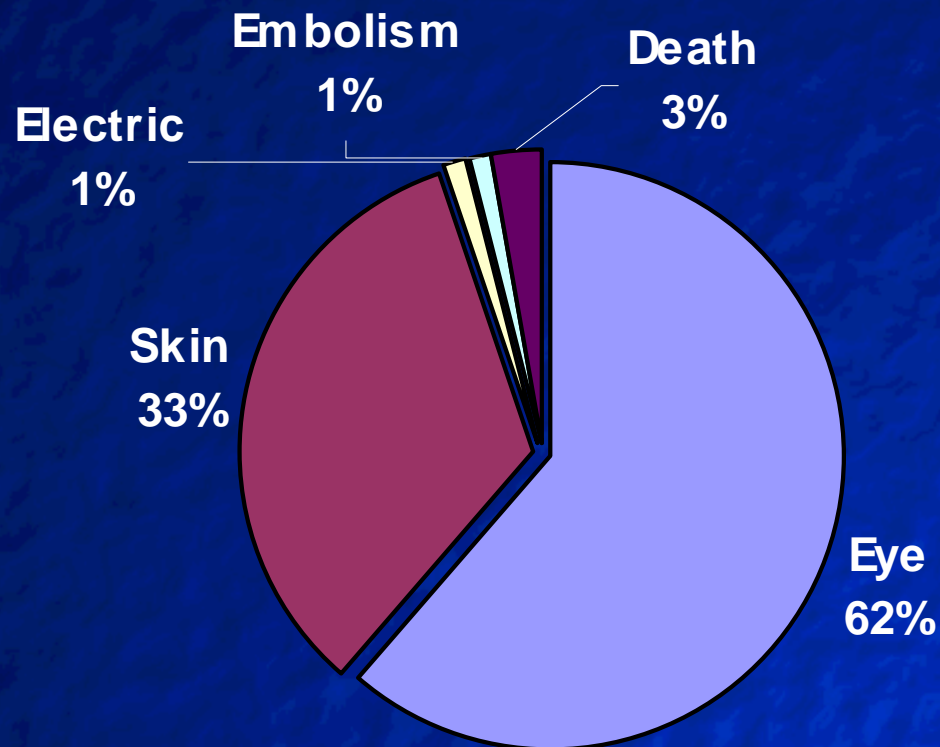
# Accidents

- Common Causes of Accidents
  - Reflective objects in beam path (clutter)
  - Grounding
  - Movement of beam path
  - Accidental energization or firing of laser
  - Bypass of Interlocks

**At CRC Call 3-SAFE**

**At BUMC Call 4-4444**

# Types of Incidents



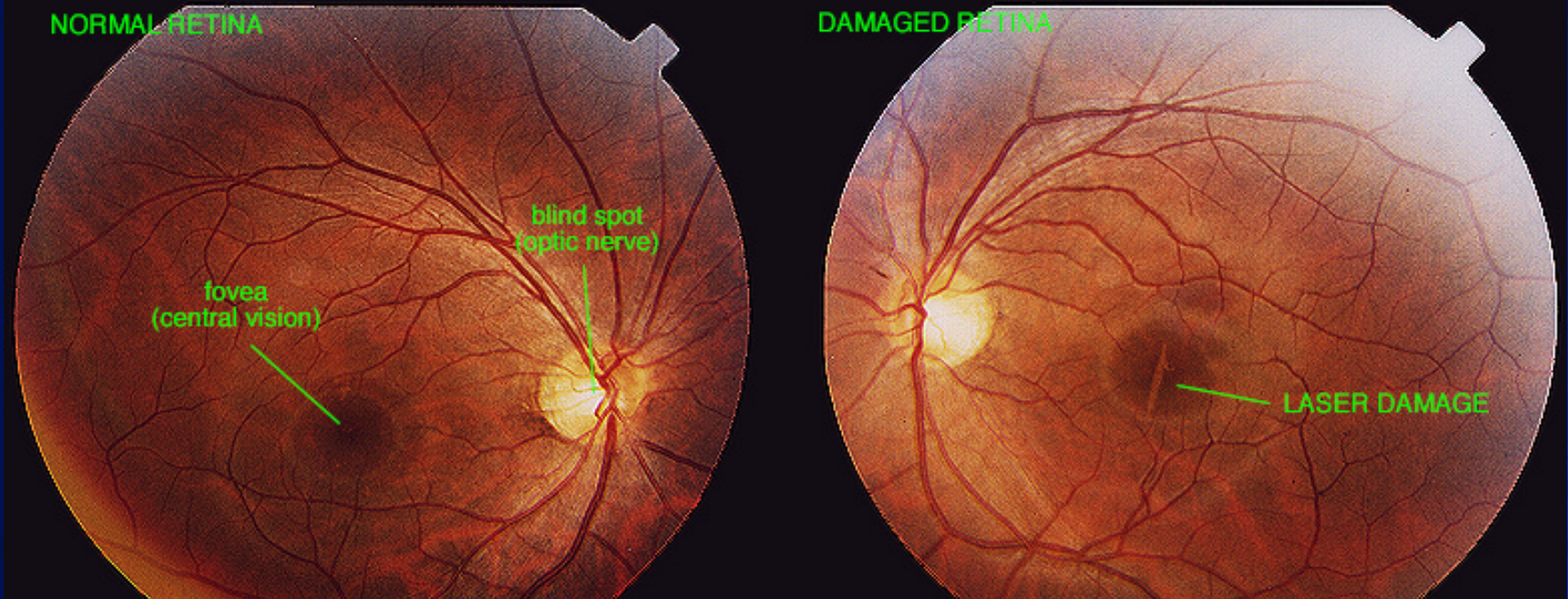
Injury, death and incident data from Clark et al. "Trends in Laser Injury Reporting" Joint International Laser Conference, 21-23 SEP03



# Common Causes of Death based on >1000 reports

- 5 electrocution—all non-hospital events
- 5 burns
- 5 air or gas embolism—1 due to improper use
- 3 airway tube fires
- 2 bleeding
- 2 improper use
- 4 no information

# Ultrashort Accident



- August 16, 1994 laser accident: A researcher working on the alignment of the compressor for a femtosecond Ti:Sapphire laser system was struck in the eye by a portion of the spectrally dispersed laser beam. The resulting split-second exposure to a 1-kHz train of broadband 20-ps pulses of at most 50 micro Joule centered at 800 nm, caused irreversible, permanent retinal damage in the eye. The person in question lost vision over a thin strip right in the middle of the central vision. While the brain may adapt to correct for this loss of vision, the injury itself cannot be remedied.

# Non-Beam Hazards

- Electrical / High Voltage
  - Most common
  - Power supplies, capacitor banks
- Chemical
  - Dye lasers
  - Compressed Gases
- Laser Generated Air Contaminants (LGAC)

# Non-Beam Hazards

- Optical
  - UV from laser welding
  - UV from discharge tubes and pumping
- Fire/Explosion
  - Ignition of gases and/or vapors
  - Electrical Wiring and Capacitor banks
- Noise
- Safe during normal use

# Laser Hazard Classes

**Lasers are classified according to the level of laser radiation that is accessible during normal operation.**

# Class 1

- Safe during normal use
- Incapable of causing injury
- Low power or enclosed beam
- Label not required
- May be higher class during maintenance or service



CLASS I Laser Product

Label not required

Nd:YAG Laser Marker

# Class 2

- Staring into beam is eye hazard
- Eye protected by aversion response
- Visible lasers only
- CW maximum power 1 mW

Laser Scanners



# CAUTION



Laser Radiation  
Do Not Stare Into Beam

Helium Neon Laser  
1 milliwatt max/cw

CLASS II LASER PRODUCT

# Class 3R (Formerly 3a)

- Aversion response may not provide adequate eye protection
- CDRH includes visible lasers only
- ANSI includes invisible lasers
- CW maximum power (visible) 5 mW

Laser Pointers



Expanded Beam

## CAUTION

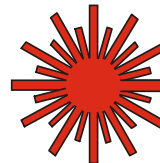


Laser Radiation-  
Do Not Stare Into Beam or View  
Directly With Optical Instruments

Helium Neon Laser  
5 milliwatt max/cw

CLASS IIIa LASER PRODUCT

## DANGER



LASER RADIATION-  
AVOID DIRECT EYE EXPOSURE

ND:YAG 532nm  
5 milliwatts max/CW

CLASS IIIa Laser Product

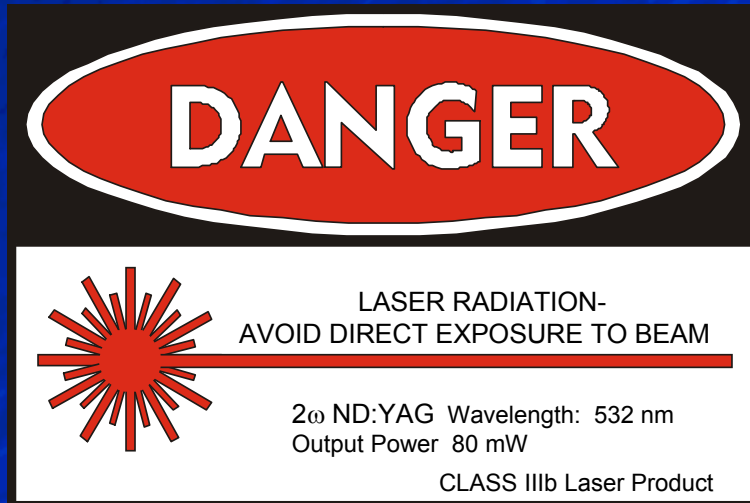
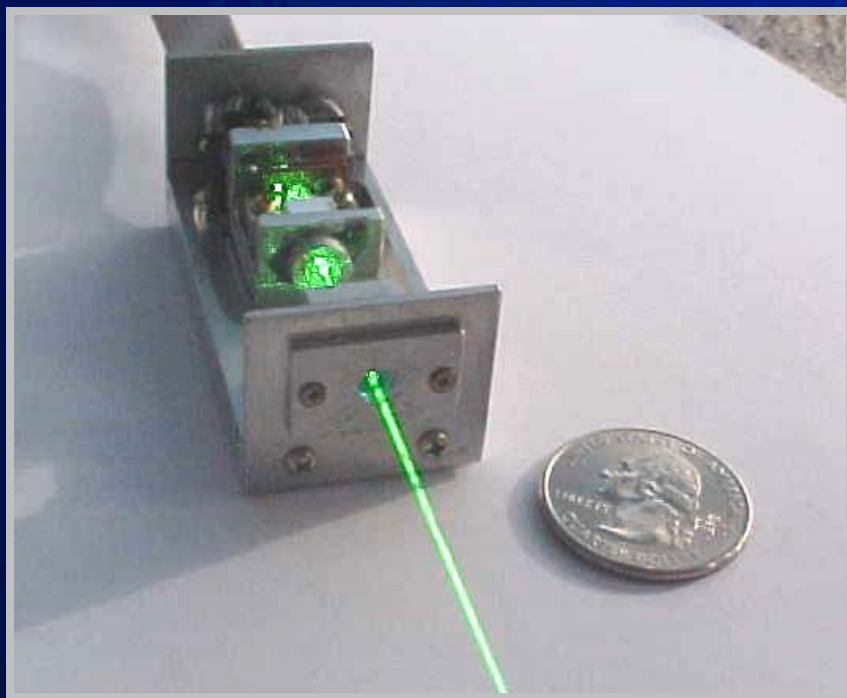
Small Beam



# Class 3B

- Direct exposure to beam is eye hazard
- Visible or invisible
- CW maximum power 500 mW

DPSS Laser with cover removed



# Class 4

- Exposure to direct beam and scattered light is eye and skin hazard
- Visible or invisible
- CW power  $>0.5$  W
- Fire hazard

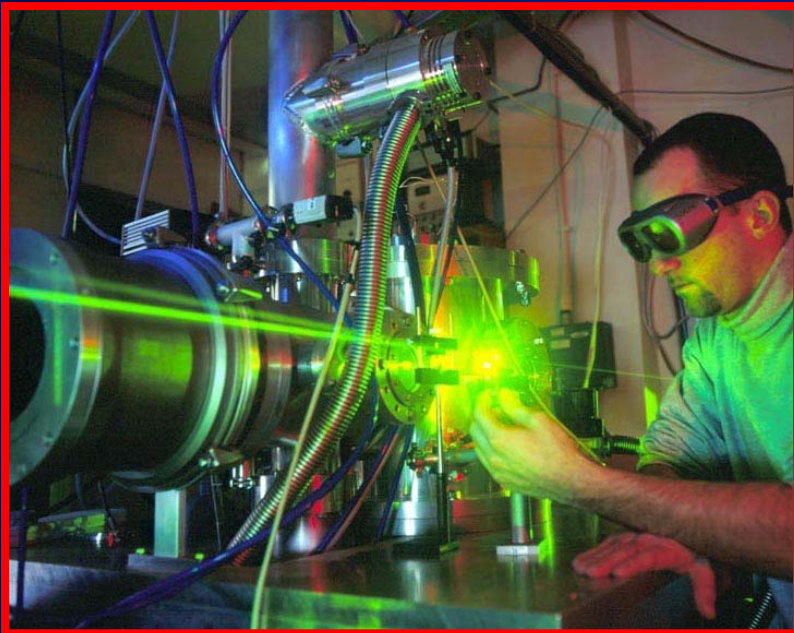


Photo: Keith Hunt - [www.keithhunt.co.uk](http://www.keithhunt.co.uk)  
Copyright: University of Sussex, Brighton (UK)



**DANGER**

VISIBLE LASER RADIATION-  
AVOID EYE OR SKIN EXPOSURE TO  
DIRECT OR SCATTERED RADIATION

2 $\omega$  Nd:YAG  
Wavelength: 532 nm  
Output Power 20 W  
CLASS IV Laser Product

# Class 1M & 2M

M is for magnification.

A class 1M laser is class 1 unless magnifying optics are used.

A class 2M laser is class 2 unless magnifying optics are used.

M classes usually apply to expanded or diverging beams.



# Laser Classification Summary

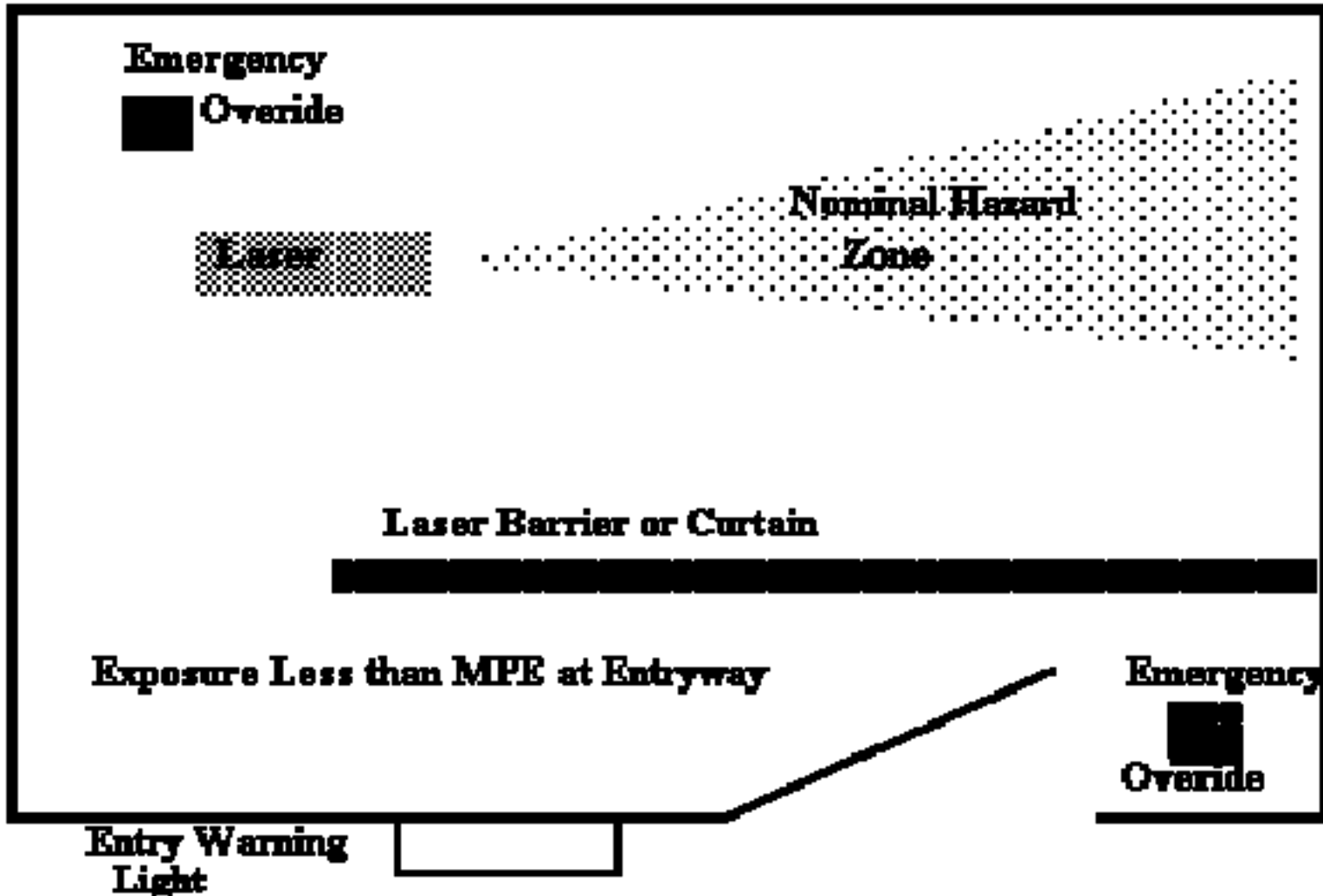
- Class 1** Incapable of causing injury during normal operation
- Class 1M** Incapable of causing injury during normal operation unless collecting optics are used
- Class 2** Visible lasers incapable of causing injury in 0.25 s.
- Class 2M** Visible lasers incapable of causing injury in 0.25 s unless collecting optics are used
- Class 3R** Marginally unsafe for intrabeam viewing; up to 5 times the class 2 limit for visible lasers or 5 times the class 1 limit for invisible lasers
- Class 3B** Eye hazard for intrabeam viewing, usually not an eye hazard for diffuse viewing
- Class 4** Eye and skin hazard for both direct and scattered exposure

# Facility Requirements

# Exposure Limits

- MPE (Maximum Permissible Exposure)
  - The highest laser energy exposure for eye or skin for a given laser
- NHZ (Nominal Hazard Zone)
  - Area within which the MPE can be met or exceeded

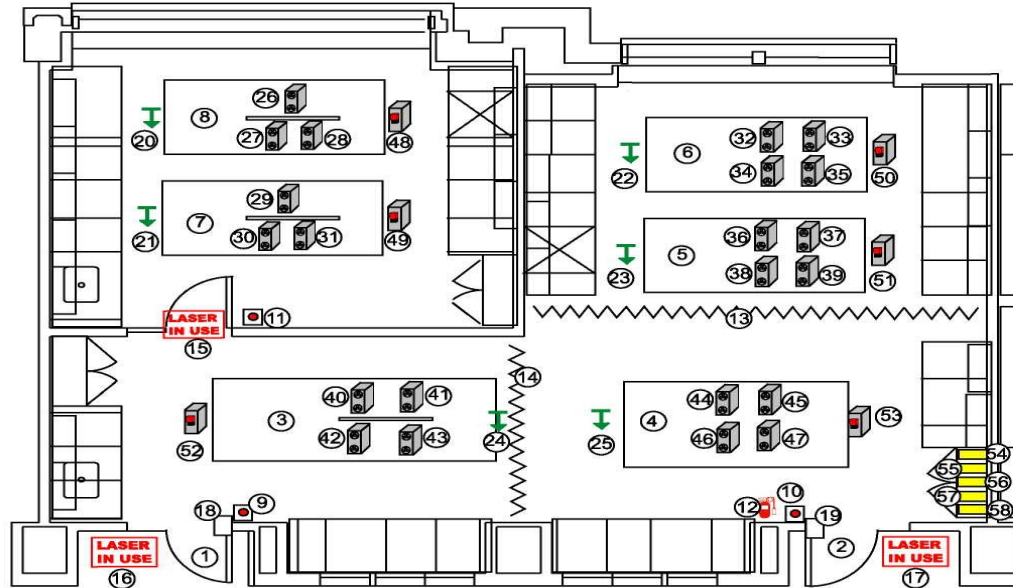
# Typical Laboratory



# Laser Facility Specification

## BOSTON UNIVERSITY SAFETY OFFICE LASER SOP FLOOR PLAN

**BUILDING:** 8 ST. MARY'S ST.      **ROOM:** 701  
**LASER SUPERVISOR:** RUANE, MICHAEL      **DATE:** 04/11/03



RP#	DESCRIPTION	RP#	DESCRIPTION	RP#	DESCRIPTION
1,2	Doors	54	Melles Griot EHS#1137		
3 - 8	Optical Tables	55	Melles Griot EHS#1139		
9 - 11	Emergency Power-Offs	56	Melles Griot EHS#1140		
12	Extinguisher	57	Melles Griot EHS#1142		
13,14	Laser Curtains	58	Melles Griot EHS#1143		
15-17	Illuminating Laser In Use Signs				
18,19	Panels				
20-25	Ground Wires				
26-47	Receptacles				
48-53	Switches				

FOR SAFE OPERATING PROCEDURES REGARDING INDIVIDUAL LASERS, PLEASE REFER TO THE LASER SAFETY MANUAL.



# Illuminated 'Laser In Use' Sign



# EPO and Laser Power Switch

## EMERGENCY POWER OFF PUSHBUTTON

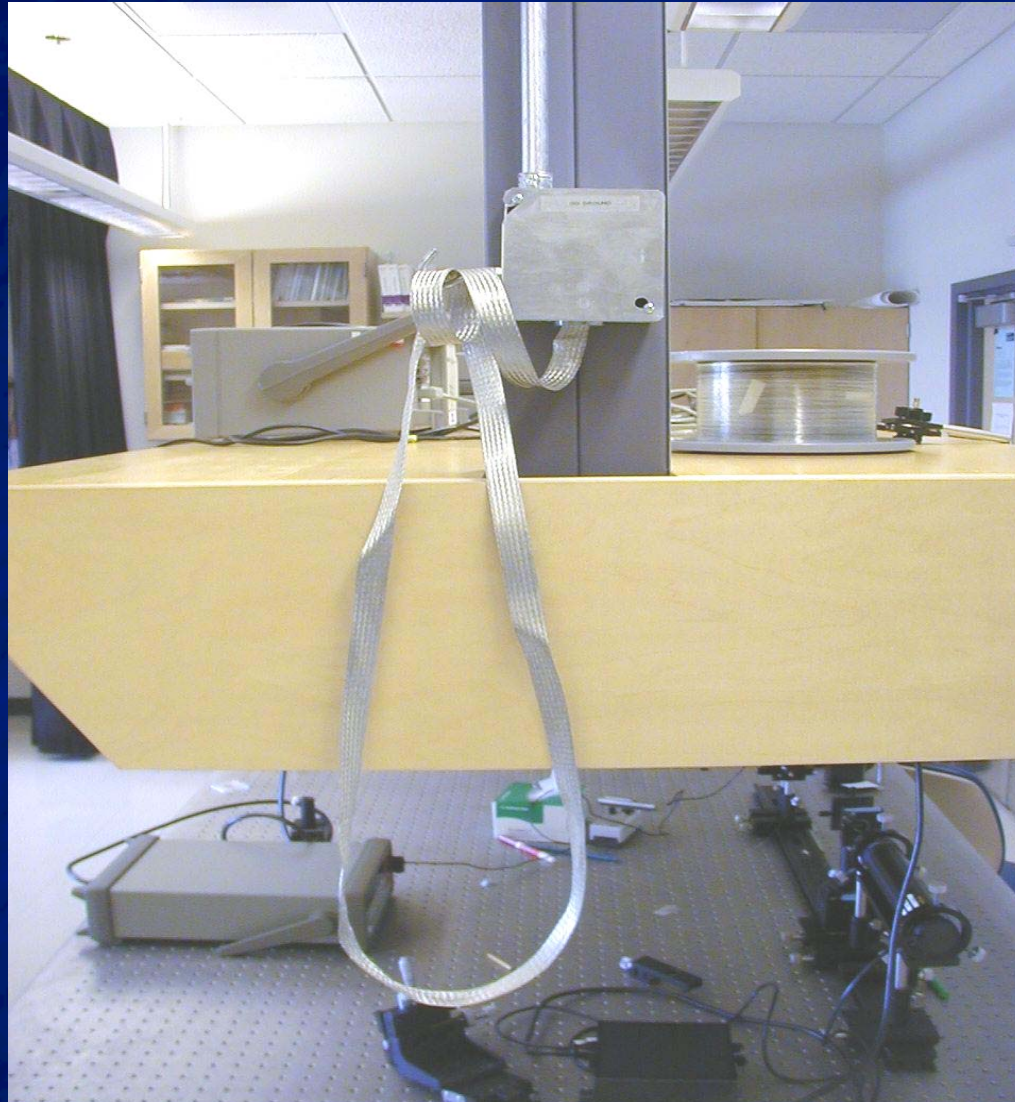
(OPERATION TRIPS ALL LAB POWER IN ROOM EXCEPT LIGHTING)

TO RESET: TO RESET TRIPPED CIRCUIT BREAKERS IN  
PANEL APL4L4  
CALL 353-2105 FOR BU OFFICE OF PHYSICAL PLANT.

CAUTION: ELECTROCUTION HAZARD: REPORT ANY  
CIRCUIT BREAKER / LAB ELECTRICAL SYSTEMS  
REWORK BEFORE IMPLEMENTATION AND FINAL  
ENERGIZATION. CALL 353-7233 FOR BU  
OFFICE OF ENVIRONMENTAL HEALTH AND SAFETY.



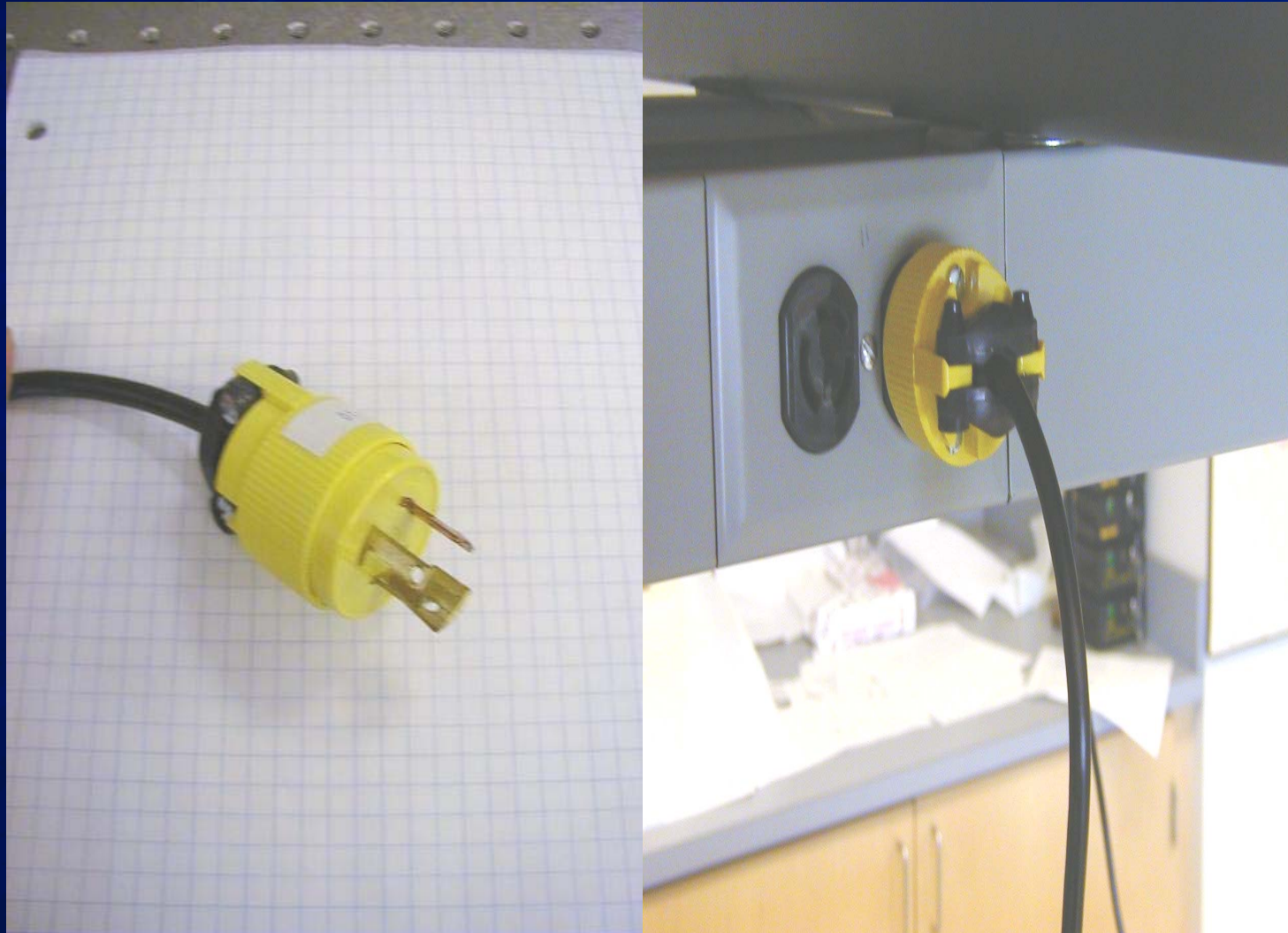
# Braided Ground Wire



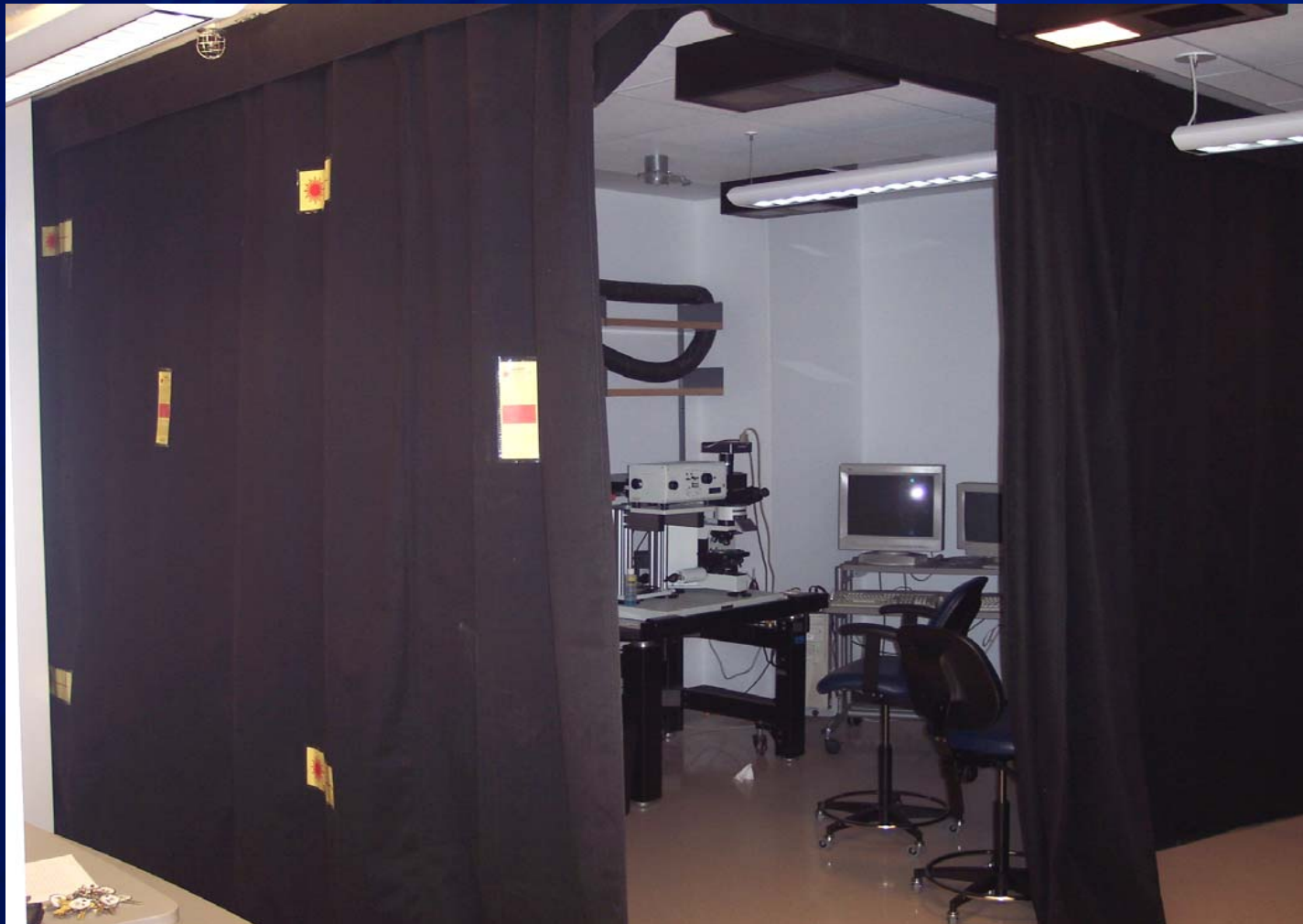
# Twist-lock Receptacles



# Twist-lock Plugs



# Laser Curtains



# Program Requirements

# Laser Safety Officer / LSO

- ANSI Z136.1 specifies that any facility using Class 3b or Class 4 lasers or laser systems should designate a Laser Safety Officer to oversee safety for all operational, maintenance, and servicing situations.
- This person should have the authority and responsibility to monitor and enforce the control of laser hazards. This person is also responsible for the evaluation of laser hazards and the establishment of appropriate control measures.



# Engineering Controls

- Beam Housings
- Shutters
- Attenuators
- Remote viewing devices
- Interlocks/Twist-lock receptacles
- Emergency Disconnects
- Laser Curtains: Wilson LP 200

# Administrative Controls

- Warning Signs
- Labels
- SOPs
- Training
- Security

# Training

- Permit Holder
- Authorized User
- Coursework Experiments / Demonstrations
- Initial
- Annual Refresher

# Personal Protective Equipment

- Eyewear
  - (appropriate for system – not necessarily highest OD)
  - Proper wavelength
  - Sufficient number for users & visitors
  - Centrally stored
- Gloves
- Viewing Devices

# Elements of BU Laser Safety Program

- Laser Safety Committee/LSO
- Laser Permits
- Equipment Registration
- Personnel Registration and Training
- Eye Exams
- SOPs and Signage
- Emergency Procedures
- Inspections and Monitoring

# Laser Permit Holder's Role

- Train users
- Write SOPs
- Select / provide PPE
- Post emergency numbers and procedures
- Allow only authorized users to enter hazard areas
- Address non-beam hazards

# Laser Alternate's Role

- To fulfill all of the Permit Holder's responsibilities during his or her absence

# Laser Liaison's Role

- To serve as point of communication with LSO
- To update all documentation and inform LSO of additions / deletions / transfers
- To coordinate training / eye exams / inspections



# Laser User's Role

- Eye Exam and Training
- Follow SOP
- Wear appropriate eyewear
- Use minimum power required/reduce output with attenuators
- Keep beam path away from eye level
- Remove unnecessary objects from table

# Communication with LSO

- Equipment inventory updates 2 X per year
- Personnel updates 3 X per year
- Prior to acquiring a new laser
- Prior to laser transfer / disposal
- Immediately upon laser exposure incident or near miss

# Equipment Labels



# Laser Permit Application

# Complete the Application Form

Submit the necessary attachments

1. Laser Equipment Inventory (3b /4)
2. Laser Personnel List
3. Laser User Authorization Form for each Laser User
4. Laser SOP for each laser/laser system

# Laser Permit Application



Radiation Protection  
Office

Evans Basement  
72 East Concord Street  
Boston, Massachusetts 02118  
Tel: (617) 638-7419  
Fax: (617) 638-7509

## Application for a Permit to Use Class 3b and Class 4 Laser Systems

### Section 1. Building Information

Building Name:	Room Number(s):
Building Address:	Department:

### Section 2. Laser Supervisor Information

Laser Supervisor:		Home Phone:
Office Phone:	Lab phone:	Email:
Laser Alternate:		Home Phone:
Office Phone:	Lab phone:	Email:

### Section 3. General Conditions:

- The proposed work shall be performed in the manner specified in the standard operating procedures. There shall be no changes in the approved procedures without the prior approval of the Office of Environmental Health and Safety.
- Routine operation of this equipment may not begin until EH&S has been notified and has conducted a thorough survey and given approval for the operation. Additional surveys shall be made by EH&S at intervals not to exceed 12 months, at which time adherence to the procedures will be determined.
- EH&S shall be notified prior to a change in the location of the equipment by the current laser supervisor.
- EH&S shall be notified of any decommissioning of the equipment or of transfer of equipment to a new laser supervisor.
- EH&S shall be notified of any changes in personnel associated with this equipment. All personnel shall be appropriately trained by EH&S and the laser supervisor before working with this equipment.

### Section 4. Required Attachments:

a.) Completed Laser Equipment Inventory for all Class 3b and Class 4 lasers.
b.) Most recently completed Personnel Update.
c.) Completed Laser User Authorization forms for each laser user.
d.) Completed Standard Operating Procedures (SOPs) for each laser noted on the Laser Equipment Inventory.

I agree to fully comply with the laser safety requirements outlined by the Massachusetts Department of Public Health (105 CMR 121, included in the Boston University Laser Safety Manual). Prior to operating laser equipment, I acknowledge that I attended a Laser Safety course provided by the BU Office of Environmental Health and Safety and that I received a baseline laser eye examination at Boston University. I will operate all laser equipment in a safe manner, and I will only operate the equipment for which I have had specific training, following the Standard Operating Procedures available in the laboratory.

Laser Supervisors' Signature: \_\_\_\_\_ Date: \_\_\_\_\_

# Laser Inventory



Radiation Protection  
Office

Evans Basement  
72 East Concord Street  
Boston, Massachusetts 02118  
Tel: (617) 638-7419  
Fax: (617) 638-7509

## Laser Inventory by Supervisor

Date: 2/3/2009

Laser Supervisor/PI:

Location (Building, Room #):

EHS#	Manufacturer	Model	Type	Serial#	Class	Medium	Delete	Explain Deletions
							<input type="checkbox"/>	
							<input type="checkbox"/>	
							<input type="checkbox"/>	
							<input type="checkbox"/>	
							<input type="checkbox"/>	

New Adds	Manufacturer	Model	Type	Serial#	Class	Medium	Add	Explain adds
							<input checked="" type="checkbox"/>	
							<input checked="" type="checkbox"/>	
							<input checked="" type="checkbox"/>	
							<input checked="" type="checkbox"/>	

It is the responsibility of the Laser Supervisor to update the Laser Equipment Inventory semi-annually, normally every January and June. The OEHS will contact the Laser Supervisor to request this information. List all laser equipment under your supervision and update as needed in the spaces provided. If you 'delete' a laser, explain where the laser was transferred. Do not dispose of any laser without OEHS approval. List any new lasers in the spaces provided.

Form Completed by: \_\_\_\_\_

# Laser Personnel Roster



Radiation Protection  
Office

Evans Basement  
72 East Concord Street  
Boston, Massachusetts 02118  
Tel: (617) 638-7419  
Fax: (617) 638-7509

## Laboratory Personnel Data

Laser Supervisor/PI:

Date: 2/3/2009

Phone:

Email:

Department:

BU ID Number	Status <sup>1</sup>	Last Name	First Name	Delete
				<input type="checkbox"/>
				<input type="checkbox"/>
				<input type="checkbox"/>
				<input type="checkbox"/>
				<input type="checkbox"/>
				<input type="checkbox"/>
				<input type="checkbox"/>
				<input type="checkbox"/>
				<input type="checkbox"/>
				<input type="checkbox"/>

### New Adds

BU ID Number	Status <sup>1</sup>	Last Name	First Name	Add
				<input checked="" type="checkbox"/>
				<input checked="" type="checkbox"/>
				<input checked="" type="checkbox"/>
				<input checked="" type="checkbox"/>
				<input checked="" type="checkbox"/>
				<input checked="" type="checkbox"/>

<sup>1</sup>. Select a status code from the choices below. **Note:** A graduate student receiving a stipend is still considered a 'student' for the purposes of this form.

E = Employee    S = Student    A = Affiliate (specify) \_\_\_\_\_

It is the responsibility of the Laser Supervisor to update the personnel listing at the beginning of each academic semester. The RPO will contact the Laser Supervisor to request this listing three times per year. List all personnel who will work with or near Class 3b/4 lasers (Authorized Users) as well as personnel who will frequent the lab, but not work directly with the lasers. The Laser Supervisor shall ensure that all listed laser personnel will have completed the appropriate level of training and medical surveillance required by the Boston University Laser Safety Program. Documentation of program requirements for authorized laser users (RPO training, SOP training and baseline eye exam) shall be recorded on the Laser User Authorization form maintained for each individual in the Laser Safety Manual. Individuals who frequent the laser lab, but do not use the lasers need only attend the RPO training session.

Form completed by:





# Laser User Authorization



Radiation Protection  
Office

Evans Basement  
72 East Concord Street  
Boston, Massachusetts 02118  
Tel: (617) 638-7419  
Fax: (617) 638-7509

LSP-6

## Laser User Authorization

Name: (print Last, First)	
BU ID Number:	

I agree to fully comply with the laser safety requirements outlined by the Massachusetts Department of Public Health (105 CMR 121, included in the Boston University Laser Safety Manual). Prior to operating laser equipment, I acknowledge that I attended a Laser Safety course provided by the BU Office of Environmental Health and Safety and that I received a baseline laser eye examination at Boston University. I will operate all laser equipment in a safe manner, and I will only operate the equipment for which I have had specific training, following the Standard Operating Procedures available in the laboratory.

BU OEHS Laser Safety Training* Date	
Laser Eye Examination* Date:	

\*See reverse for scheduling information

### Laser Standard Operating Procedure Training

Laser Name & Class	Laser Ref. No.	Laser Location Bldg. Address Room #	Training Date	Trained By (print)

User Signature:	Print:	Date:
Supervisor Signature:	Print:	Date:

The laser supervisor shall maintain one up-to-date copy of the Laser User Authorization form for each laser user in the Laser Safety Manual.



# Laser Standard Operating Procedure



Radiation Protection  
Office

Evans Basement  
72 East Concord Street  
Boston, Massachusetts 02118  
Tel: (617) 638-7419  
Fax: (617) 638-7509

LSP-4 **LASER STANDARD OPERATING PROCEDURE** OEHS Number <#>  
for \_\_\_\_\_

Contact	Office Phone #	Emergency Phone #
Permit Holder:		
Alternate:		
Liaison:		
Safety Officer: Ron Slade	617-353-4094	617-353-7233

## Location

Building Location	Room Number

## Revision History

Revision	Description of Changes	Effective Date	Author
A	Initial Release:		

## Approvals

Name and Title	Signature	Date

The Laser SOP will be reviewed biennially as part of the permit renewal process. Any proposed changes to the SOP must first be approved by both the Laser Permit Holder and the Laser Safety Officer.

# Laser Safety Exercise

**Can you identify safe and/or unsafe conditions?**



PLATE FROM SPALY LOCATED IN RM. 102

**DANGER**  
HIGH VOLTAGE  
KEEP OUT

WIRE FROM BULK HEAD

VWR brand  
BY WELCH





MELLES

02/10/2004

# For Additional Information

- **Office of Medical Physics and Radiation Safety**
  - Laser Safety Officer: Ron Slade, 638-8828
  - MC Main Office (Business Hours): 638-7052
  - MC Emergency (24 Hours): 414-4444
  - MC Fax: 638-7509
  - CRC Main Office: 353-4094
  - CRC Emergency (24 Hours): 353-7233 (SAFE)
  - CRC Fax: 353-5646
  - Web site: [www.bu.edu/research/compliance/oehs/mprs](http://www.bu.edu/research/compliance/oehs/mprs)
- **MA DPH Radiation Control Program**
  - 105 CMR 121.000 Regulations for the Control of Lasers
  - Web site: [www.state.ma.us/dph/rcp.radia.htm](http://www.state.ma.us/dph/rcp.radia.htm)
- **ANSI Z-136 Series (esp. Z136.1 and Z136.5)**