

Laser Safety Training

Carnegie Mellon
University

Environmental
Health and
Safety

- Mark Banister
- Andrew Lawson



What? A test already?

- How can you avoid the need for laser safety classes?
- What steps would you take if you get a new laser in your lab?
- What would make a Class 1 imbedded laser a Class 4 laser?

Two More...

- What special steps might you need to take when you align your laser beam?
- Where would you go for any laser safety questions?

Introduction

Lasers are used and are present in many different areas with many different applications here at Carnegie Mellon.

Following the procedures and activities presented in this training module will help prevent harm to you, your co-workers and the University.

Training Overview

This training module is in two parts:

1. Part 1 is designed for **ALL** campus laser equipment users.
2. Part 2 provides additional information for users of **Class IIIb** and **Class IV** laser systems, as these lasers have the potential for more serious hazards.

PART ONE

Laser Training for **ALL** Laser Users

Carnegie Mellon's Laser Safety Program

- Laser safety is coordinated through the department of Environmental Health and Safety (EH&S)
- Program elements are enforceable through
 - OSHA General Duty Clause
 - OSHA Lab Standard
 - OSHA Substance Specific Standards
- Written policies and procedures are found at

http://ehs-alert.fms.bap.cmu.edu/LabSafety/Chemical_Safety/chemsafety.php#lasersafety

Safety Program Elements

- University Laser Safety Officers (LSO)
- A written **Laser Safety Program**
- Applicable standards addressing laser use
- Laser Definition, Inventory and Classification
- Hazard Analysis and Hazard Control
- Medical Surveillance (Class IIIb and IV only)
- Emergency Response
- Inspections

Laser Safety Officer

Overseeing the laser safety program at the university are two Laser Safety Officers, both within EH&S:

- Mark Banister (markb2@andrew.cmu.edu)
- Andrew Lawson (alawson@andrew.cmu.edu)

Applicable Standards

- ANSI Z136.1-Safe Use of Lasers (2000)
- ANSI Z136.5-Safe Use of Lasers in Educational Institutions (year?)
- ANSI Z136.6-Safe Use of Lasers Outdoors (2000)
- ANSI/NFPA 70 National Electric Code (1996)

Laser Identification and Classification

What is a laser?

- **LASER** means-Light Amplification by Stimulated Emission of Radiation.
- Laser light is non-ionizing.
- May be UV (100-400nm), visible (400-700nm) or infrared (700nm to 1mm).

Laser Basics

Lasers are unique when compared to conventional light sources in that they are:

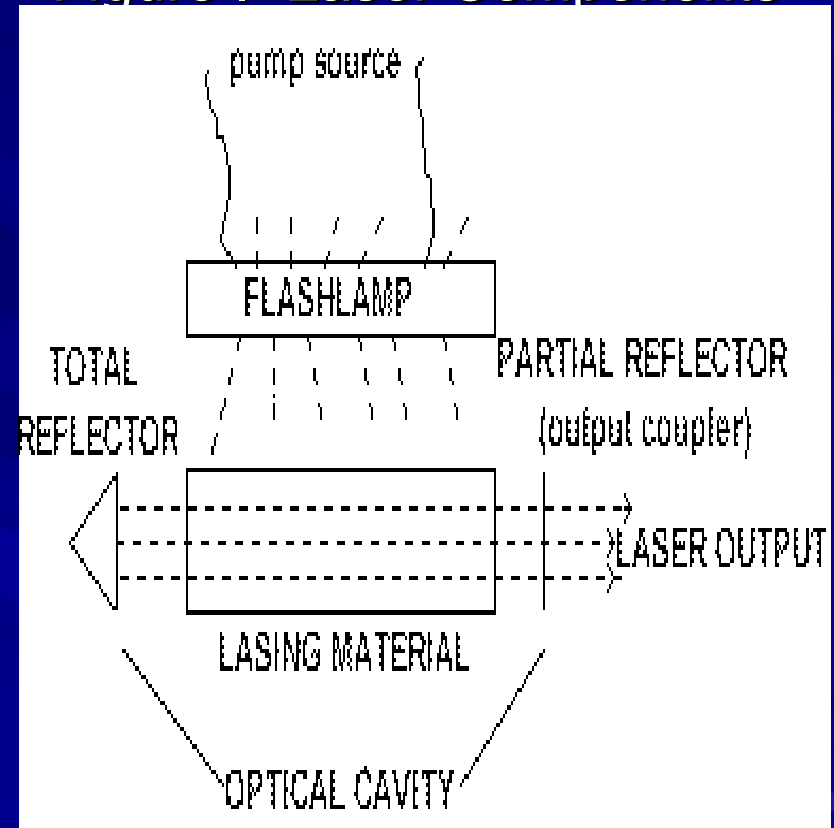
- Monochromatic-all of the light produced by the laser is of a single wavelength
- Coherent-the waves of light are in phase with each other
- Directional-the beam of light has very low divergence

Components of a Laser

Lasers consist of the following components:

- Lasing media (gas, solid, liquid, semiconductor)
- Excitation mechanism (power supply, flashlamp, laser)
- Total reflector or feedback mechanism (mirror or grating)
- Laser output (partially reflecting mirror)

Figure I- Laser Components



Laser Classes



- All manufacturers are required to identify the laser class of all systems
- A sample label is to the left
- Older lasers or systems that have been modified must be classified by the Laser Safety Officer

**Do You Know What
Class Laser You
Have?**

Elements used in Classification

I. Lasing Media

- Gas (CO₂, Argon Ion, Excimer)
- Solid (Neodymium YAG, Titanium Sapphire)
- Semiconductor (Gallium-Arsenide)
- Dye

II. Mode of Operation

- Continuous wave (cw)
- Pulsed (<0.25 sec.)
- Q-switched

III. Wavelength- dependent upon Lasing Media used

- Ultraviolet (180-400 nm)
- Visible (400-700 nm)
- IR region (700 nm-1mm)

The following chart illustrates the wavelengths associated with various types of laser systems

LASER TYPE	WAVELENGTH (Nanometers)
Argon Fluoride	193
Xenon Chloride	308 and 459
Xenon Fluoride	353 and 459
Helium Cadmium	325 - 442
Rhodamine 6G	450 - 650
Copper Vapor	511 and 578
Argon	457 - 528 (514.5 and 488 most used)
Frequency doubled Nd:YAG	532
Helium Neon	543, 594, 612, and 632.8
Krypton	337.5 - 799.3 (647.1 - 676.4 most used)
Ruby	694.3
Laser Diodes	630 - 950
Ti:Sapphire	690 - 960
Alexandrite	720 - 780
Nd:YAG	1064
Hydrogen Fluoride	2600 - 3000
Erbium:Glass	1540
Carbon Monoxide	5000 - 6000
Carbon Dioxide	10600

Laser Classifications

Class I

This class denotes lasers that are not hazardous for continuous viewing or are designed in such a way that prevents human access to laser radiation.

These consist of low power lasers or high power embedded lasers (i.e. laser printers, CD players)

Laser Classifications

Class II

This class denotes low-power visible lasers or laser systems which because of the normal human bright-light aversion response (i.e. blinking, eye movement etc.) do not normally present a hazard, but may present some potential for hazard if viewed directly for extended periods of time (like many conventional light sources) (1 mW or less)

Laser Classifications

Class IIIa

- This sub-class denotes lasers or laser systems that normally would not injure the eye if viewed for momentary periods with the unaided eye, but a hazard may be present if viewed using collecting optics. The source is typically less than 5mW.
- Most laser pointers are Class IIIa.

Laser Classifications

Class IIIb

This sub-class denotes lasers or laser systems that can produce a hazard if viewed directly, including intrabeam viewing of specular reflections. Normally Class 3b lasers will not produce a hazardous diffuse reflection from a matte target. (500 mW)

Laser Classifications

Class IV

This class denotes lasers or laser systems that produce a hazard not only from direct or specular reflections, but may also produce hazardous diffuse reflections. Such hazards may produce significant skin hazards as well as fire hazards.

Laser Inventory

- It is critical to the Laser Safety Program to identify *all* lasers and laser users on campus.
- It is also necessary to collect and maintain information as to the type, number, class, power, etc., of all lasers, to ensure that proper application of safety protocol is achieved.
- The inventory form used is located at the Chemical Safety section of the EH&S webpage.
- **Do we have your laser information?**

Laser Inspections

- All laser systems should be inspected by the LSO and PI at least once every two years for class I, II and IIIa lasers.
- Inspections should be performed annually by the LSO and the PI for class IIIb and IV laser systems.

Laser Hazards

Laser Hazards

- Like most hazardous items, there are specifications defining a “safe” exposure.
- Again, like most situations, it is appropriate not only to be in the “safe range” of exposure, but also minimize exposures as much as possible in the “safe range”.

Maximum Permissible Exposure

- For lasers, the “safe” exposure is defined to be below the MPE, or Maximum Permissible Exposure level.
- This number is widely variable, depending on the power, wavelength, exposure period and other laser-specific factors
- The LSO should determine all MPEs

Laser Hazards

There are many sources of hazards inherent in laser systems:

- Radiation, producing biological and medical effects
- Chemical hazards
- Electrical hazards
- Compressed gas hazards

Radiation Hazards

- Can produce damage to eyes and skin.
 - Laser radiation is more of a hazard than regular light due to its single wavelength, and its directional and coherent energy.
- Critical factors are:
 - Wavelength
 - Energy of the beam
 - Duration of exposure
 - Whether exposure is from pulsation laser

Summary of Laser Biological Effects-Eyes

<u>Photobiological Spectral Domain</u>	<u>Eye</u>
Ultraviolet C (200 nm - 280 nm)	Photokeratitis
Ultraviolet B (280 nm - 315 nm)	Photokeratitis
Ultraviolet A (315 nm - 400 nm)	Photochemical cataract
Visible (400 nm - 780 nm)	Photochemical and thermal retinal injury
Infrared A (780 nm - 1400 nm)	Cataract and retinal burn
Infrared B (1.4mm - 3.0 mm)	Corneal burn, aqueous flare, cataract
Infrared C (3.0 mm - 1000 mm)	Corneal burn only

Summary of Laser Biological Effects-Skin

<u>Photobiological Spectral Domain</u>	<u>Skin</u>
Ultraviolet C (200 nm - 280 nm)	Erythema (sunburn), skin cancer, accelerating skin aging
Ultraviolet B (280 nm - 315 nm)	Increased pigmentation
Ultraviolet A (315 nm - 400 nm)	Pigment darkening, Skin burn
Visible (400 nm - 780 nm)	Pigment darkening, Photosensitive reactions, Skin burn
Infrared A (780 nm - 1400 nm)	Skin burn
Infrared B (1.4mm - 3.0 mm)	Skin burn
Infrared C (3.0 mm - 1000 mm)	Skin burn

Summary of Bioeffects of Commonly Used Lasers

LASER TYPE	WAVELENGTH H (μm)	BIOEFFECT Process	TISSUE EFFECTED			
			Skin	Cornea	Lens	Retina
CO ₂	10.6	Thermal	X	X		
HFI	2.7	Thermal	X	X		
Erbium-YAG	1.54	Thermal	X	X		
Nd-YAG [a]	1.33	Thermal	X	X	X	X
Nd-YAG	1.06	Thermal	X			X
Gas (diode)	0.78-0.84	Thermal				X
He-Ne	0.633	Thermal				X
Ar	0.488-0.514	Thermal/ Photochemical	X			X[c]
XeFl	0.351	Photochemical	X	X		X
XeCl	0.308	Photochemical	X	X		

Chemical Hazards

- I. Laser Dye
- II. Flammable solvents
- III. Non-polar solvents
- IV. Possible spills and leaks



Laser Dye Hazards

Solvents used for dye lasers may pose a variety of health hazards both chemical and physical.

Laser Dye Hazards

- I. Concentrated powder form
- II. Type of solvent used
- III. Many are known or suspected carcinogens, toxins, and mutagens

Hazards Associated with Compressed Gases

- I. Unsecured cylinders
- II. Ventilation
- III. Incompatibilities
- IV. Toxicity of gases themselves



Hazards Associated with Secondary Laser Emissions

- I. Hazardous gases are often exhausted from gas lasers (i.e. excimer lasers), requiring proper ventilation
- II. Laser ablation targets can produce hazardous fumes or vapors and require proper ventilation

Non-Beam Radiation Hazards

Non-beam radiation is incoherent radiation that is not the same wavelength as the laser, that is generated by the operation of the laser or laser system components

- For lasers with voltages >15 kV, X-rays can be generated by accelerating electrons that are rapidly decelerating
- Optical radiation produced from pump sources such as flash lamps, electrical discharges, etc.
- Some laser systems can also produce RF radiation.

Electrical Hazards

- I. High voltage and current
- II. Capacitors



Laser Hazard Control

Hazard Analysis

- The Laser Safety Officer, in conjunction with the PI, should evaluate possible hazards of the laser system, including:
 - eye exposure
 - skin exposure
 - chemical exposure
 - electric shock potential
 - fire hazard

Hazard Control

- Administrative Controls
- Engineering Controls
- Protective equipment

We will discuss each of these....

Administrative Controls

- Warning Signs and Labels
- Use minimum power energy required for the project
- Written Standard Operating Procedures¹
- Education and training
- Medical monitoring²
- Service by authorized personnel
- Nominal Hazard Zones²

¹ Mandatory for Class IIIb & IV, encouraged for all

² For Class IIIb & IV only

Warning Signs

- For Class 1 lasers:
 - No warning sign is needed.
- For Class 2 lasers:
 - Post warning at entrance to operating area.
 - Sign to read “Caution - Laser Radiation - Do not stare into beam”.



Warning Signs

- For Class 3a lasers:
 - Post warning at entrance to operating area.
 - Sign to read “Caution-Laser Radiation - Do Not Stare into Beam or View Directly with Optical Instruments)”.



Warning Signs

- For Class 3b lasers:
 - Post warning at entrance to operating area.
 - Sign to read “Danger - Laser Radiation - Avoid Direct Exposure to Beam”.



Warning Signs

For Class 4 lasers:

- Post warning at entrance to operating area.
- Sign to read “Danger - Laser Radiation - Avoid Eye or Skin Exposure to Direct or Scattered Radiation”.



Warning Signs and Labels

Lasers that have been modified must be labeled in-house.

- Modified lasers must be classified by the Laser Safety Officer; the LSO must approve all modifications.

Engineering Controls

General Controls:

- Master key
- Interlocks
- Consider remote firing of unit
- Remove unnecessary objects from vicinity of laser
- Securely mount the laser to maintain the beam in a fixed position and limit beam traverse during adjustments.

Engineering Controls

Beam Controls:

- Reduce laser output with shutters and attenuators
- Terminate longer beams with beam stops
- Keep beam path away from eye level, either sitting or standing
- Use curtains to control specular reflections
- Enclose any beam path that exits from a controlled area, where the irradiance exceeds the MPE.
- Ensure that beam paths do not cross populated areas or traffic paths. Confine the beams and reflections to the optical table; beam terminators for wavelengths over 710nm should be of fire resistant materials (class 3b and 4).

Engineering Controls

Viewing and alignment controls

- Use diffuse reflective screens or remote viewing systems during alignment if possible

Personal Protective Equipment

- Protective eyewear—always wear it when an exposure is possible
- Gloves
- Face shields
- Protective aprons

Protective Equipment

- Eyewear selection depends on:
 - Wavelength
 - Optical Density
 - Comfort
 - Field of view
 - Effect on color vision
 - Power/pulse of radiation
- Consult with EH&S for selection determination—eyewear is **VERY** specific to a laser and is typically **NOT** interchangeable between systems.

Chemical Hazard Control

- Control any dyes as hazardous chemicals where appropriate, as stated on the MSDS.
- Minimize storage of chemicals near laser systems.
- Evaluate potential hazards from hazardous gases, such as fluorine. EH&S can provide assistance.
- Evaluate potential hazards from interaction of the beam with chemical materials. EH&S can provide assistance.

Electrical Hazard Control

■ Electrical

- Mark all system shut-offs clearly.
- All electrical installation, operation and maintenance must conform to National Electric Code (contact EH&S for information).

System Specific Information

- Detailed information for your specific laser system must be obtained from the PI or Safety Supervisor in your area.
- Additional information may be obtained from the Laser Safety Officers:
 - Mark Banister 8-1493 (primary)
 - Andrew Lawson 8-8405 (secondary)
- Or by contacting Environmental Health and Safety at 8-8182.

Emergency Response

- In the event of a an overexposure of a person to laser radiation, the following steps should be taken:
 - ***Immediately*** contact University Police to ensure that the affected person(s) receive(s) medical treatment.
 - Contact EH&S and report the incident to the LSO.
 - If the incident involves chemical hazards, follow lab emergency response protocol on Emergency Response Guide posted in each lab.

Common Causes of Accidents

- Altering beam path by adding optical components without regard to the beam path
- Inserting reflective objects into beam path (i.e. jewelry and watches)
- Not terminating the beam properly
- Bypassing interlocks (particularly during alignment procedures)
- Accidental firing of lasers

PART TWO

Laser Training for users of
Class IIIb and IV laser systems

Special Issues

- Special activities are necessary for the safe use of these “more hazardous” laser systems. They include:
 - Medical monitoring
 - Standard Operating Procedures
 - Special controls and protective equipment

Medical Monitoring

- Eye examinations are recommended for users of Class 3b and Class 4 lasers.
- The baseline eye examination will include:
 - Ocular history
 - Visual acuity and macular function test
 - Color vision test
 - Examination of eye
 - Skin examination (optional)
- Contact EH&S for details of eye exams

Standard Operating Procedures

- They are **REQUIRED** to be prepared for lasers of Class 3b and Class 4.
- Should be prepared for the following:
 - Operation, including any unattended operation
 - Use of safety equipment and safeguards
 - Maintenance, set-up and calibration
- The SOPs should be remain accessible in the work area to all applicable users.

Explosion Hazards

Potential sources include:

- Flash lamps
- Capacitors
- Solvents and compressed gases
- Laser targets or optical components can shatter from high intensity beams

Fire Hazards

Potential sources include:

- Electrical circuits
- Improper beam enclosure
- Ignition of gases/vapors
- Flammable solvents

Fires can be initiated by an electrical arc or by the beam from a Class 4 laser. Ensure that flammable and combustible materials are stored away from beam paths.

Nominal Hazard Zone

- Based on the hazard analysis, a Nominal Hazard Zone (NHZ) is identified.
- The NHZ is an area inside which the Maximum Permissible Exposure (MPE) may be exceeded.
- Only authorized persons may be inside the NHZ.
- Applicable to Class 3b and 4, generally.

Specific Laser System Controls

- Special controls will be discussed for your specific laser systems. . .