The University of Mississippi

1848

BASIC LASER SAFETY

The Laboratory Services Division(LS)
of
Facilities Management

Course Outline

- **Laser fundamentals**
  - Laser theory and operation
  - Components
  - Types of lasers
- **Laser hazards**
  - How they are classified
- **Laser control measures**
  - Warning signs and labels
  - Protective equipment
- **Laser safety at Ole Miss**

Laser Definitions

LASER is the acronym for **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation.

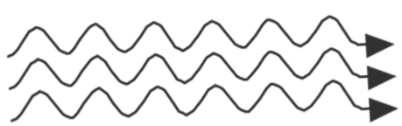
LASER is a process

Laser is a Device

Laser light

- is monochromatic, unlike ordinary light which is made of a spectrum of many wavelengths. Because the light is all of the same wavelength, the light waves are said to be synchronous.
- is intense, directional and focused so that it does not spread out from the point of origin.

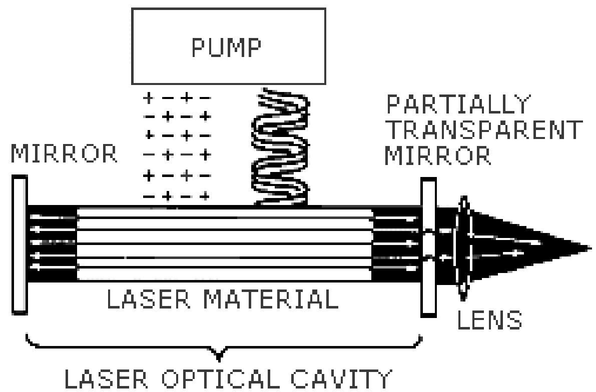
Synchronous Light Waves
Directional / Monochromatic



Asynchronous Light Waves
Multi-Directional Light

How a Laser Works

A laser consists of an optical cavity, a pumping system, and an appropriate lasing medium.



Optical Cavity - contai h mirrors to redirect the produced photons back along the same general path.

Pumping System - uses photons from another source as a xenon gas flash tube (optical pumping) to transfer energy to the media, electrical discharge within the pure gas or gas mixture media (collision pumping), or relies upon the binding energy released in chemical reactions to raise the media to the metastable or lasing state.

Laser Medium - can be a solid (state), gas, dye (in liquid), or semiconductor. Lasers are commonly designated by the type of lasing material employed.

Laser Medium

- The laser medium can be a solid (state), gas, dye (in liquid), or semiconductor. Lasers are commonly designated by the type of lasing material employed.

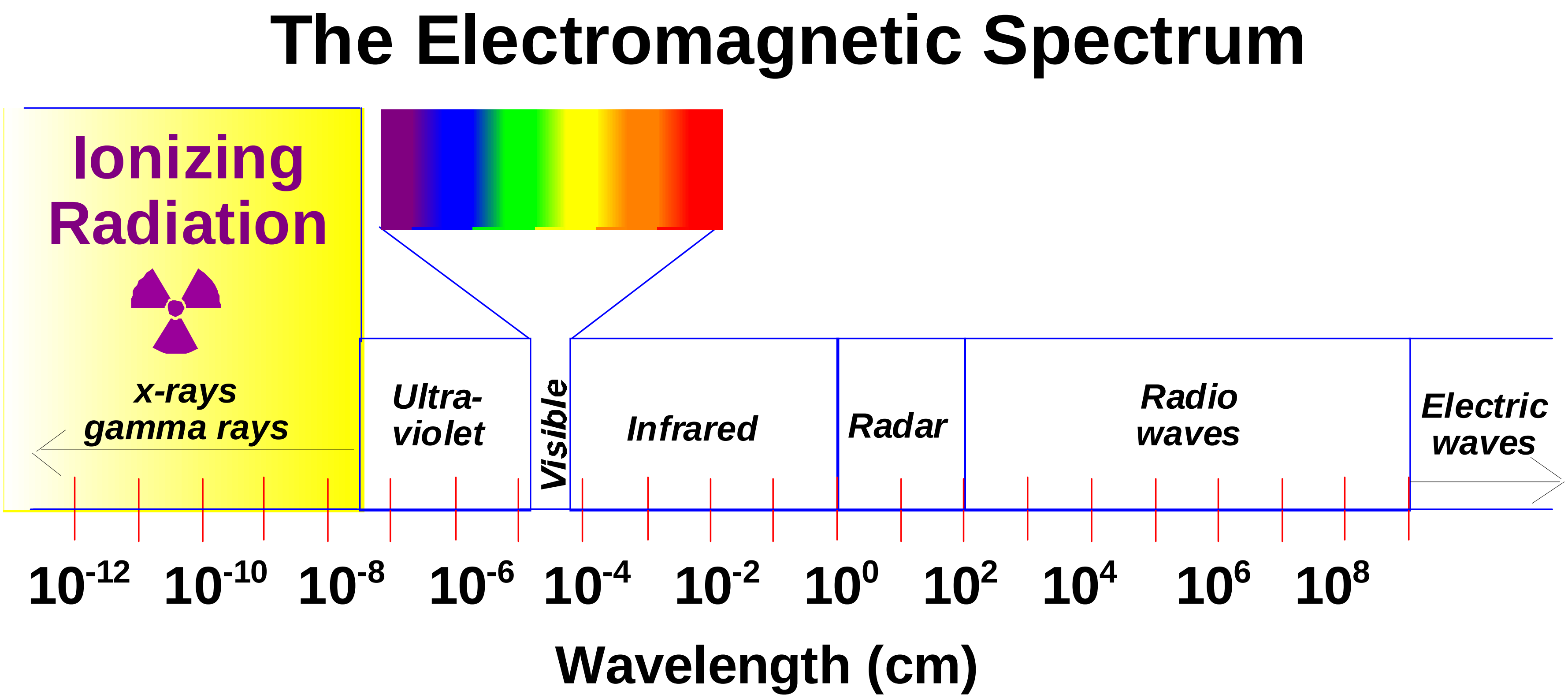
- **Solid state lasers** have lasing material distributed in a solid matrix, e.g., the ruby or neodymium-YAG (yttrium aluminum garnet) lasers. The neodymium-YAG laser emits infrared light at 1.064 micrometers.
- **Gas lasers (helium and helium-neon, HeNe**, are the most common gas lasers) have a primary output of a visible red light. CO2 lasers emit energy in the far-infrared, 10.6 micrometers, and are used for cutting hard materials.
- **Excimer lasers** (the name is derived from the terms excited and dimers) use reactive gases such as chlorine and fluorine mixed with inert gases such as argon, krypton, or xenon. When electrically stimulated, a pseudomolecule or dimer is produced and when lased, produces light in the ultraviolet range.
- **Dye lasers** use complex organic dyes like rhodamine 6G in liquid solution or suspension as lasing media. They are tunable over a broad range of wavelengths.
- **Semiconductor lasers**, sometimes called diode lasers, are not solid-state lasers. These electronic devices are generally very small and use low power. They may be built into larger arrays, e.g., the writing source in some laser printers or compact disk players.

Types of Lasers

- Lasers can be described by:
  - which part of the electromagnetic spectrum is represented
    - Infrared
    - Visible Spectrum
    - Ultraviolet
  - the length of time the beam is active
    - Continuous Wave – laser output is steady (output = watts)
    - Pulsed (output = energy)
    - Q-switched - laser pulse duration is extremely short (nanoseconds)

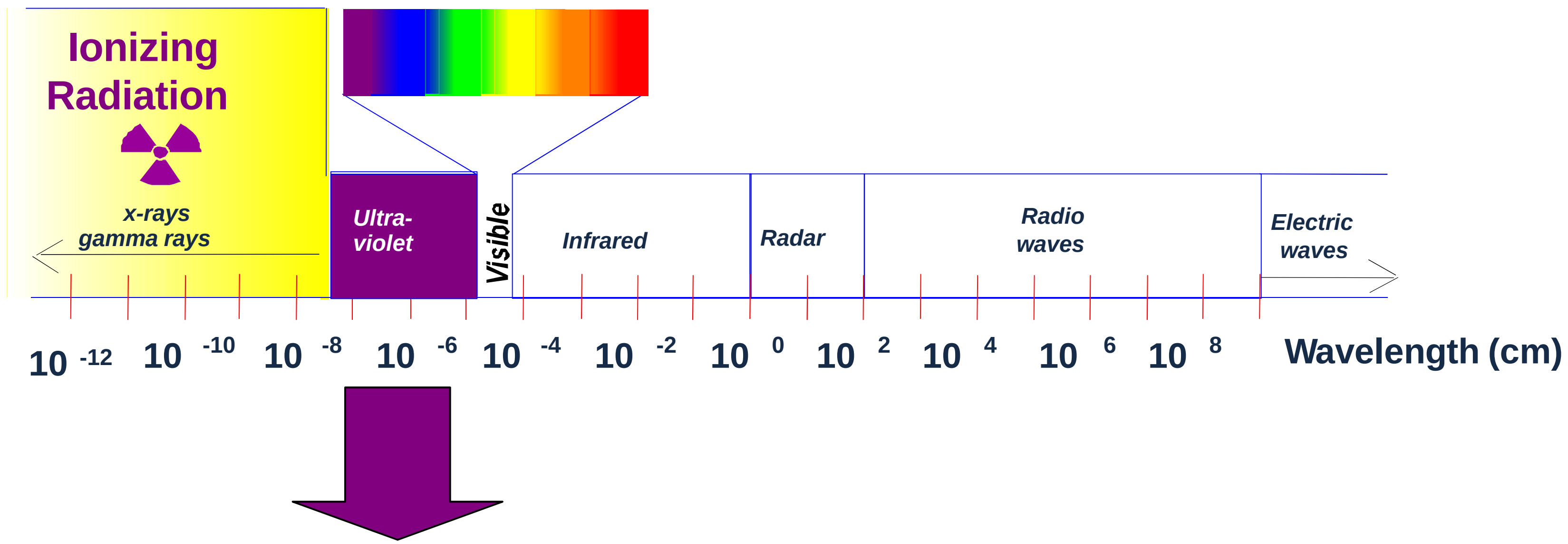
Electromagnetic Spectrum

Laser wavelengths are usually in the Ultraviolet, Visible or Infrared Regions of the Electromagnetic Spectrum.



Common Ultraviolet Lasers

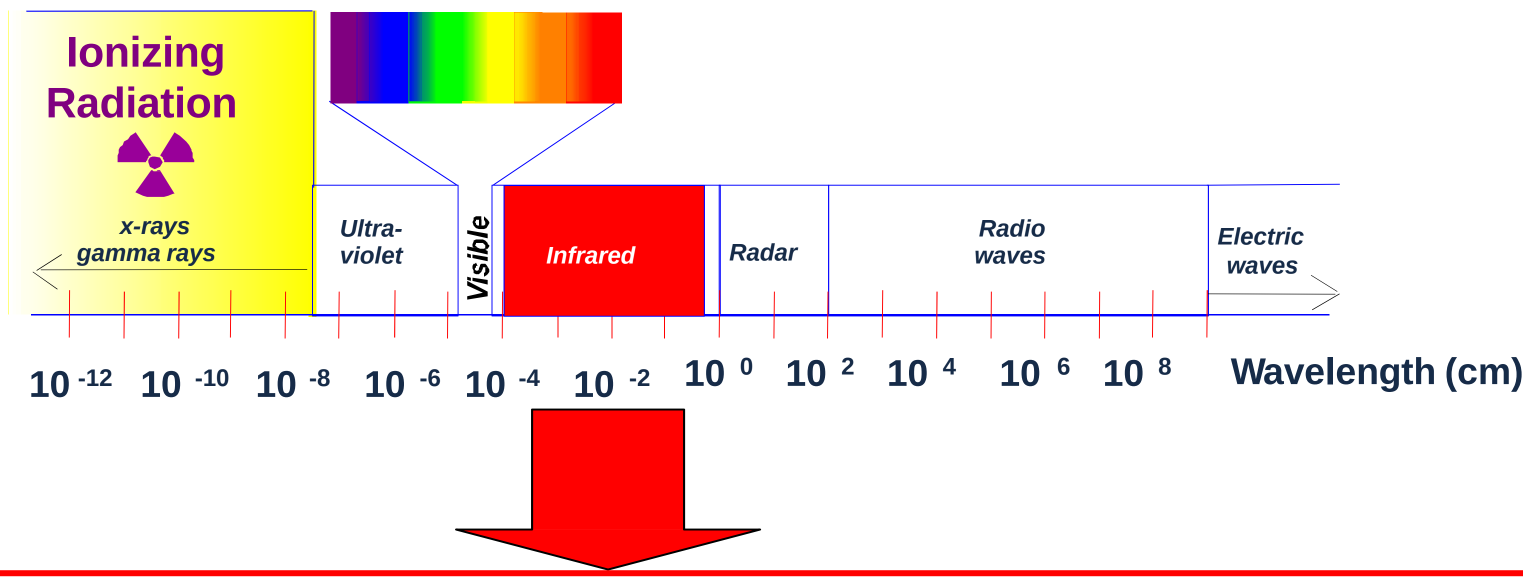
Ultraviolet (UV) radiation ranges from 200-400 nm.



Common Ultraviolet Lasers						
Argon fluoride	Krypton chloride	Krypton fluoride	Xenon chloride	Helium cadmium	Nitrogen	Xenon fluoride
193 nm	222 nm	248 nm	308 nm	325 nm	337 nm	351 nm

Common Infrared Lasers

Infrared radiation ranges from 760-1,000 nm.



Common Infrared Lasers								
Near Infrared							Far Infrared	
Ti Sapphire	Helium neon	Nd:YAG	Helium neon	Erbium	Hydrogen fluoride	Helium neon	Carbon dioxide	Carbon dioxide
800 nm	840 nm	1,064 nm	1,150 nm	1,504 nm	2,700 nm	3,390 nm	9,600 nm	10,600 nm

THE UNIVERSITY of MISSISSIPPI

Common Visible Light Lasers

Violet	Helium cadmium	441 nm
Blue	Krypton	476 nm
	Argon	488 nm
Green	Copper vapor	510 nm
	Argon	514 nm
	Krypton	528 nm
	Frequency doubled Nd YAG	532 nm
	Helium neon	543 nm
Yellow	Krypton	568 nm
	Copper vapor	570 nm
	Rohodamine 6G dye (tunable)	570 nm
	Helium neon	594 nm
Orange	Helium neon	610 nm
Red	Gold vapor	627 nm
	Helium neon	633 nm
	Krypton	647 nm
	Rohodamine 6G dye	650 nm
	Ruby ($CrAlO_3$)	694 nm

The wavelength range for light that is *visible* to the eye ranges from 400-760 nm.

Laser Hazards

Beam/Reflection hazards

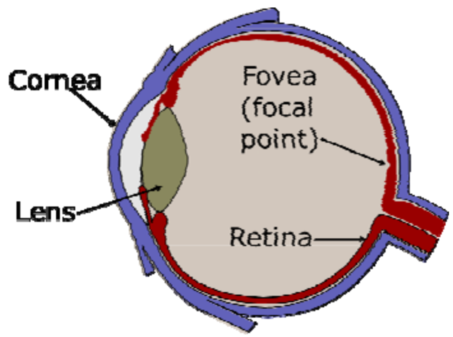
- **Intra-beam exposure** the eye or skin is exposed directly to all or part of the laser beam. The eye or skin is exposed to the full irradiance or radiant exposure possible.

- **Specular reflection** is a reflection from a mirror-like surface. A laser beam will retain all of its original power when reflected in this manner.
  - *Note that surfaces which appear dull to the eye may be specular reflectors of IR wavelengths.*

- **Diffuse reflection** is a reflection from a dull surface.
  - *Note that surfaces that appear shiny to the eye may be diffuse reflectors of UV wavelengths. Diffuse laser light reflection from a high powered laser can result in an eye injury.*

Biological Damage

Retina



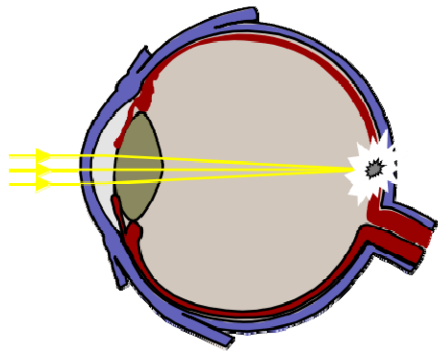
- **Thermal damage** to the retina occurs in the Retinal Hazard Region (from 400 nm – 1400 nm). Thermal damage is not cumulative, as long as the retina cools down between exposures.

- **Photochemical damage** is severe at shorter visible wavelengths (violet & blue) and is cumulative over a working day.

- **Acoustic shock** from exposure to high energy pulsed lasers results in physical tissue damage.

Retinal Hazard Region

- The wavelength range of light that can enter the eye is 400 to 1400 nm, though the range that we can actually see is only 400 – 760 nm.

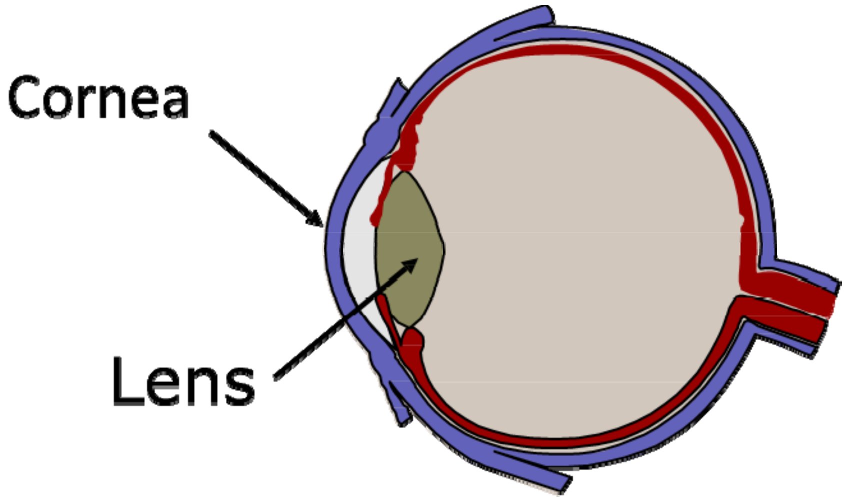


- The eye can focus a collimated beam of light to a spot 20 microns in diameter on the retina (called the focal point).
- This focusing ability places the retina at risk when exposed to laser light in the wavelength range that will penetrate to the retina, because even fairly low wattage laser light can impact the retina with 100,000 times the radiant power that entered the eye. Because of this optical gain, laser light in the 400 – 1400 nm is referred to as the Retinal Hazard Region.
- This is important to remember when working with infrared lasers, because the retina can be injured even though the laser is invisible.

Biological Hazards

Cornea & Lens

- Inflammation injury to the cornea is caused by ultraviolet (UV) wavelengths (200-400 nm). This is the same type of injury that is caused by snow blindness.
- Chronic exposure can cause cataract formation in the lens of the eye just as UV from the sun does.



Biological Hazards - Skin

- **Ultraviolet (UV)**
  - UV can cause skin injuries comparable to sun burn.
  - As with damage from the sun, there is an increased risk for developing skin cancer from UV laser exposure.

- **Thermal Injuries**

  High powered (Class 4) lasers, especially from the infrared (IR) and visible range of the spectrum, can burn the skin and even set clothes on fire.

Summary of Biological Damage

<table>
<tr><th>Spectral region</th><th>Eye</th><th>Skin</th></tr>
<tr><td>Ultra-violet C
(180 nm to 280 nm)</td><td rowspan="2">Photokeratitis</td><td rowspan="2">Erythema (sunburn)
Accelerated skin ageing</td></tr>
<tr><td>Ultra-violet B
(280 nm to 315 nm)</td></tr>
<tr><td>Ultra-violet A
(315 nm to 400 nm)</td><td>Photochemical cataract</td><td rowspan="2">Pigment darkening
Photosensitive Reactions
Skin burn</td></tr>
<tr><td>Visible
(400 nm to 780 nm)</td><td>Photochemical & thermal retinal injury</td></tr>
<tr><td>Infra-red A
(780 nm to 1400 nm)</td><td>Cataract, retinal burn</td><td rowspan="3">Skin burn</td></tr>
<tr><td>Infra-red B
(1,4 μm to 3,0 μm)</td><td rowspan="2">Aqueous flare, cataract, corneal burn
Corneal burn only</td></tr>
<tr><td>Infra-red C
(3,0 μm to 1 mm)</td></tr>
</table>

Common **Unsafe** Practices

Preventable laser accidents

- Not wearing protective eyewear during alignment procedures
- Not wearing protective eyewear in the laser control area
- Misaligned optics and upwardly directed beams
- Improper methods of handling high voltage
- Available eye protection not used
- Intentional exposure of unprotected personnel
- Lack of protection from non-beam hazards

Common **Unsafe** Practices

Preventable laser accidents

- Failure to follow (Laser) Safety Instructions
- Bypassing of interlocks, door and laser housing
- Insertion of reflective materials into beam paths
- Lack of pre-planning
- Turning on power supply accidentally
- Operating unfamiliar equipment
- Wearing the wrong eyewear

Preventing Accidents

during Alignment

- No unauthorized personnel will be in the room or area.
- Laser protective eyewear will be worn.
- The individual who moves or places an optical component on an optical table is responsible for identifying and terminating each and every stray beam coming from that component.
- To reduce accidental reflections, watches and reflective jewelry must be taken off before any alignment activities begin.
- Beam blocks must be used and must be secured.
- When the beam is directed out of the horizontal
- plane, it must be clearly marked.

Preventing Accidents

during Alignment

- The lowest possible/practical power must be used during alignments.
- Have beam paths that differ from the eye level when standing or sitting. Do not use paths that tempts one to bend down and look into the beam.
- All laser users must receive an introduction to the laser area by the authorized laser supervisor of that area

PI Responsibilities

- PI's have the primary responsibility for safety in the research area.
  - Notify the LSO of the purchase or acquisition of lasers.
  - Preparing the research area to meet applicable safety requirements before the arrival of a laser.
  - Maintaining the records of medical surveillance for laser operators as necessary.
  - Ensuring that all operators complete the required safety training and, when necessary, hands-on training provided by the laser manufacturer.
  - Preparing a detailed standard operating procedure (SOP) outlining the methods and requirements for the use of a laser before operations begin. This SOP must be approved by the LSO.

University Laser Safety Regulations

- **Policy**: Laser Safety Manual
- Summary/Purpose : The Laser Safety Manual details the minimum requirements and procedures for operations involving Lasers.
- University Policy Number: 10000316
- Code: ADM.EC.300.002
- Status: Approved and Activated
- Administrative Division: VC FOR ADMINISTRATION & FINANCE
- Responsible Office: LABORATORY SERVICES
- Effective Date: 05/08/2007

- http://safety.olemiss.edu/safety-programs/laser-safety/
  - Laser Safety Manual
  - Laser Safety Forms
  - Laser Safety Tables

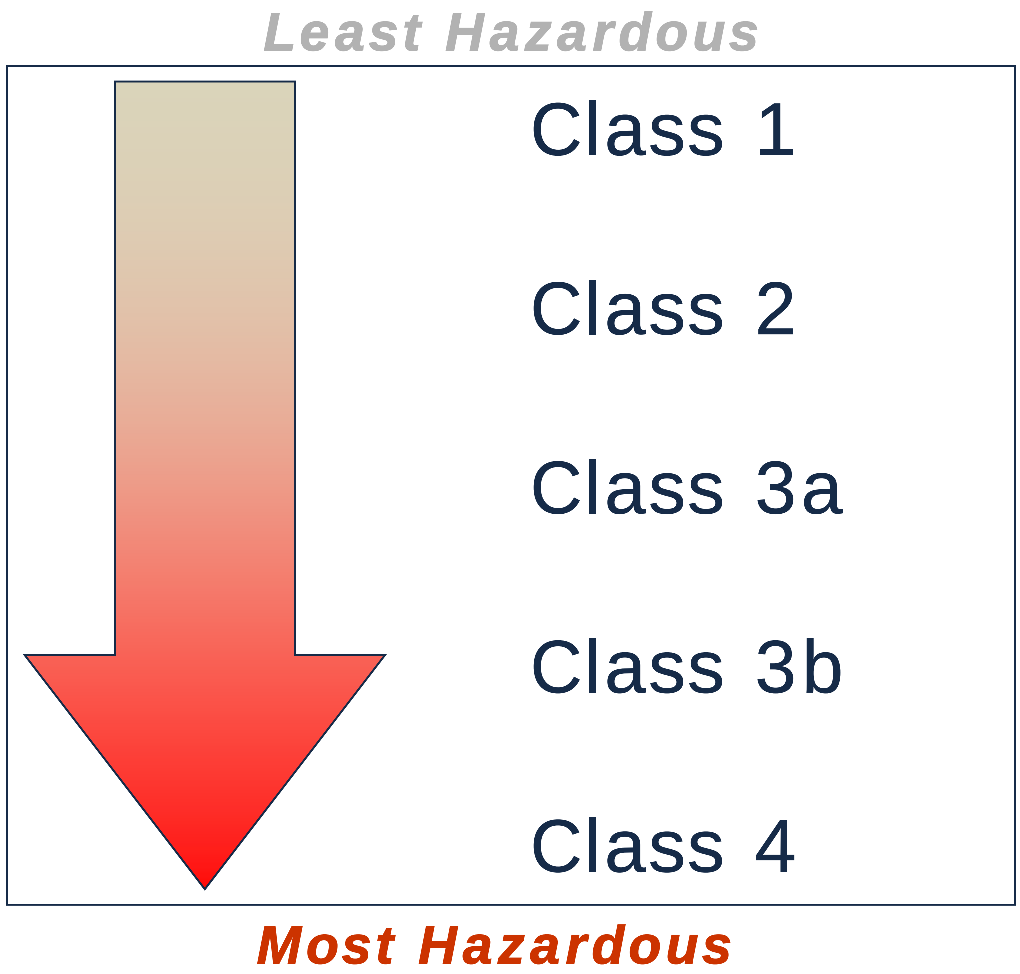
ANSI Z136.1 - Safe Use of Lasers

- American National Standard for Safe Use of Lasers
- Laser Institute of America

- The ANSI Z136.1 Standard is the foundation of laser safety programs for industrial, military, medical, and educational applications nationwide.
- Z136.1 provides guidance for the safe use of lasers and laser systems by defining control measures for each laser hazard classifications.

Laser Hazard Classes

Class 1	0 – 0.4 microwatts
Class 2	0.4 microwatts – 1.0 milliwatts
Class 3A	1.0 milliwatts – 5.0 milliwatts
Class 3b	5.0 milliwatts – 500 milliwatts
Class 4	power exceeds 500 milliwatts



Class 1 Lasers

- This class cannot produce a hazardous beam because it is of extremely low power,
- Or
- because it has been rendered intrinsically safe due to the laser having been completely enclosed so that no hazardous radiation can escape and cause injury.

Class 2 Lasers

- These lasers are visible light (400-760 nm) continuous wave or pulsed lasers which can emit energy greater than the limit for Class I lasers and radiation power not above 1 mW.
- This class is hazardous only if you stare directly into the beam for a long time, which would be similar to staring directly at the sun.
- Because class 2 lasers include only visible wavelengths, the aversion reaction will usually prevent us from permanently damaging our eyes.The aversion reaction refers to our tendency to look away from bright light.

Class 3a Lasers

- This class of intermediate power lasers includes any wavelength.
- Only hazardous for intrabeam viewing.
- This class will not cause thermal skin burn or cause fires.

Class 3b Lasers

- Visible and near-IR lasers are very dangerous to the eye.
- Pulsed lasers may be included in this class.
- This class will not cause thermal skin burn or cause fires.
- Requires a Laser Safety Officer(LSO) and written Standard Operating Procedures(SOPs).

Class 4 Lasers

- These high-powered lasers are the most hazardous of all classes.
- Visible and near-IR lasers may cause severe retinal injury and burn the skin.
- Even diffuse reflections can cause retinal injuries.
- UV and far-IR lasers of this class can cause injury to the surface of the eye and the skin from the direct beam and specular reflections.
- This class of laser can cause fires.
- Requires a Laser Safety Officer(LSO) and written Standard Operating Procedures(SOPs).

Laser Safety Officer (LSO)

- The Laser Safety Officer (LSO) has authority to monitor and enforce the control of laser hazards and enforce University policies and regulations.
- All Class 3b and 4 lasers must have an LSO.

Maximum Permissible Exposure
(MPE)

- The Maximum Permissible Exposure (MPE) is the highest level of radiation to which a person can be exposed without hazardous effects.
- The MPE is specified in W/cm2 for continuous wave lasers and in J/cm2 for pulsed lasers. The value depends on wavelength, exposure duration and pulse repetition frequency.
- Exposure to radiation levels in excess of the MPE will result in adverse biological effects, such as injury to the skin and/or eyes.

Nominal Hazard Zones
(NHZ)

- The Nominal Hazard Zone (NHZ) is the location around the laser within which a person can be exposed to radiation in excess of the MPE.
- When Class 3b and 4 lasers are unenclosed, the Laser Safety Officer must establish a NHZ.
- People may be injured if they are within the perimeter of this zone while the laser is in operation.

Non-Beam Hazards

Non-beam hazards refer to anything other than the laser itself that can create a hazard.

- This type of hazard includes:
  - Electrical Hazards
  - Fire Hazards
  - Laser Generated Air Contaminants (LGAC)
  - Compressed Gases
  - Chemical Hazards
  - Collateral and Plasma Radiation
  - Noise

Control Measures

- Lab specific training, SOPs and research procedures must detail non beam hazards and control measures to prevent injury. **Always** follow area postings and requirements, and use lab specific controls.

- These measures may include:
  - Engineering Controls
  - Administrative Controls
  - Personnel Protective Equipment
  - Warning Signs and Labels

Engineering Controls

- Engineering controls are
  - measures that are incorporated into the laser system,
  - designed to prevent injury to personnel, and,
  - preferable to PPE or Administrative controls.

- Examples include
  - Protective housings
  - Interlocks on Removable protective housings
  - Service access panels
  - Key control master switch (Class 3b & 4)
  - Viewing Windows, Display Screens, Collecting Optics
  - Beam path enclosures
  - Remote interlock connectors (Class 3b & 4)
  - Beam Stop or attenuator (Class 3b & 4)
  - Curtains between laser systems

Administrative Controls

- Administrative controls are procedures that are designed to prevent personnel from injury. Examples of administrative controls required for Class 3b & 4 lasers include:
  - Designation of Nominal Hazard Zones (NHZ).
  - Written Standard Operating Procedures (SOP's)
  - Warning signs at entrances to room.
  - Training for all personnel who will be operating the laser or in the vicinity of the laser while it is in operation. (Training is also required for those using Class 2 and 3a lasers.)
  - Allow only authorized, trained personnel in the vicinity of the laser during operation.

Personnel Protective Equipment (PPE) for Skin

exposed to Class 3b or 4 lasers

- Ultraviolet lasers and laser welding/cutting operations may require that tightly woven fabrics be worn to protect arms and hands. Sun screen may also be used to provide some additional protection.
- For lasers with wavelengths > 1400 nm, large area exposures to the skin can result in dryness and even heat stress.

Personnel Protective Equipment (PPE) for Eyes

- PPE is not required for class 2 or 3a lasers unless intentional direct viewing > 0.25 seconds is necessary.
- PPE for eyes exposed to Class 3b or 4 lasers is mandatory. Eyewear with side protection is best.
  - Consider these factors when selecting eyewear:
  - Optical Density (OD) of the eyewear
  - Laser Power and/or pulse energy
  - Laser Wavelength(s)
  - Exposure time criteria
  - Maximum Permissible Exposure (MPE)
  - Filter characteristics, such as transient bleaching

Other Personnel Protective Equipment (PPE)

- PPE may also be required to provide protection from hazardous chemicals and gases.
- Consult with Laboratory Services if you need assistance with determining the appropriate PPE for use in your lab or with your laser.

Warning Labels

Only Class 1 lasers require no labels. All other lasers must be labeled at the beam's point of origin.

- **Class 2:**
  - "Laser Radiation – Do Not Stare into Beam."
- **Class 3a:**
  - "Laser Radiation – Do not Stare into Beam or View Directly with Optical Instruments."
- **Class 3b:**
  - "Laser Radiation – Avoid Direct Eye Exposure."
- **Class 4:**
  - "Laser Radiation – Avoid Eye or Skin Exposure to Direct or Scattered Radiation."

Warning Signs

- All rooms with class 3a, 3b or 4 lasers must have appropriate signs posted at all entrances. Signs must:
  - Warn of the presence of a laser hazard in the area
  - Indicate specific laser safety policies
  - Indicate the relative hazard such as the Laser Class and the location of the Nominal Hazard Zone
  - Indicate precautions needed such as PPE requirements for eyewear, etc.

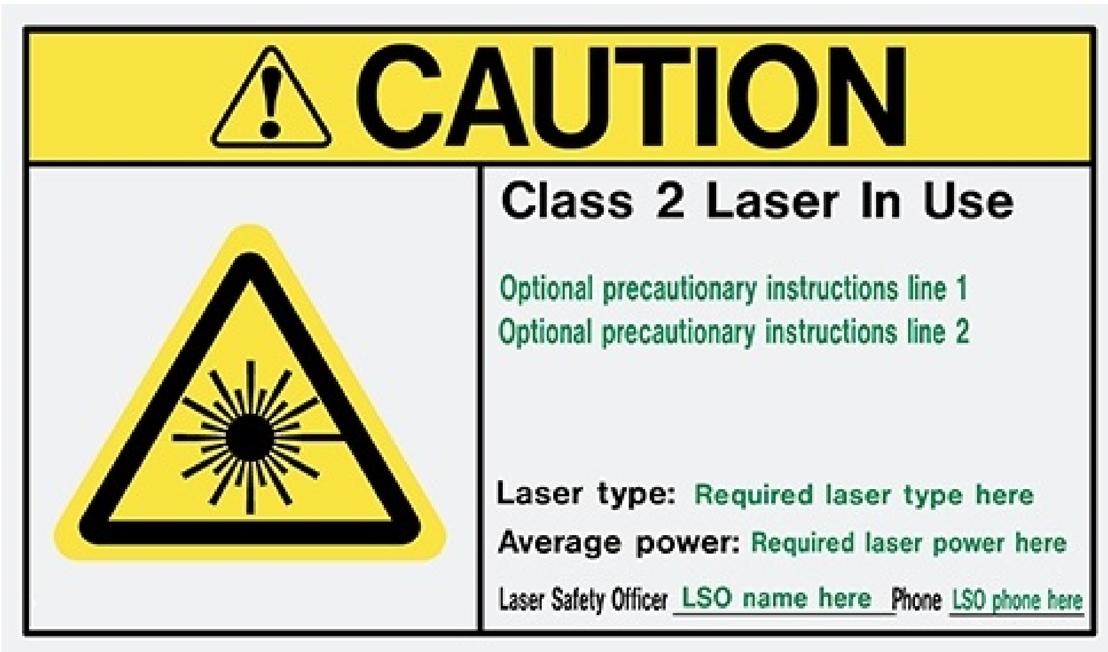
Laser Warning Signs

“DANGER” indicates a very dangerous situation that could result in serious injury or death. This sign should be used for Class 3b and 4 lasers.

“CAUTION” indicates a potentially hazardous situation which could cause a less serious injury. This sign should be used for Class 2 and 3a lasers.

“NOTICE” does *not* indicate a hazardous situation. This sign should only be used to make people aware of facility policies regarding laser safety and/or to indicate that a repair operation is in progress.

“CAUTION” Warning Sign



Safety Instructions may include:

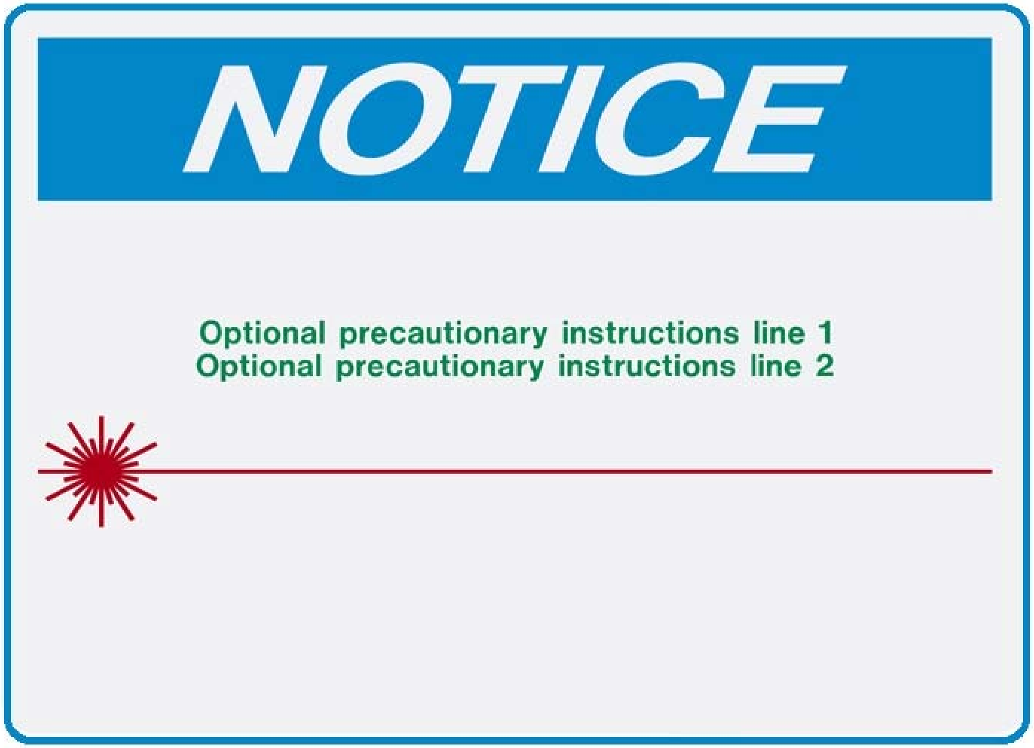
- Eyewear Required
- Invisible laser radiation
- Knock Before Entering
- Do Not Enter When Light is On
- Restricted Area

“DANGER” Warning Sign

Safety Instructions may include:

- Eyewear Required
- Invisible laser radiation
- Knock Before Entering
- Do Not Enter When Light is On
- Restricted Area

“NOTICE” Sign for Laser Repair



Safety Instructions may include:

- Eyewear Required
- Invisible laser radiation
- Knock Before Entering
- Do Not Enter When Light is On
- Restricted Area

Additional Warnings

3b & 4 Lasers

- The Nominal Hazard Zone (NHZ) must be marked so that the boundary of the NHZ is clearly defined.
- An audible alarm, warning light or a verbal “countdown” is required before activation.
- A visible warning light should flash when the laser is in operation and the light should be readily visible through protective eyewear.

The Laboratory Services Division(LS)

of
Facilities Management
Phone - 5433

Call Laboratory Services any time have any safety questions or concerns.

Biosafety

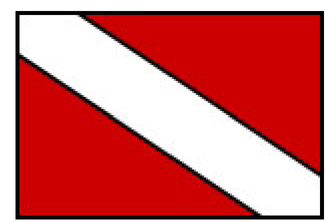
Diving Safety

Chemical Safety

Controlled Substances

Laser Safety

Radiation Safety



THE UNIVERSITY of MISSISSIPPI