Laser Safety at UNLV

UNLV Department of Risk Management

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 UNLV

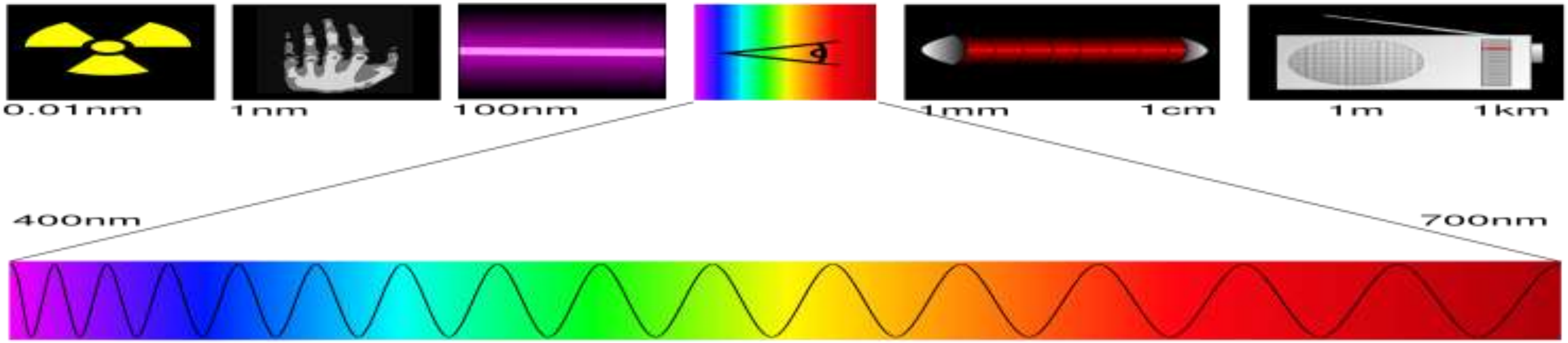
To help protect your privacy, PowerPoint prevented this external picture from being automatically downloaded. To download and display this picture, click Options in the Message Bar, and then click Enable external content.

LASER

- Light Amplification by Stimulated Emission of Radiation

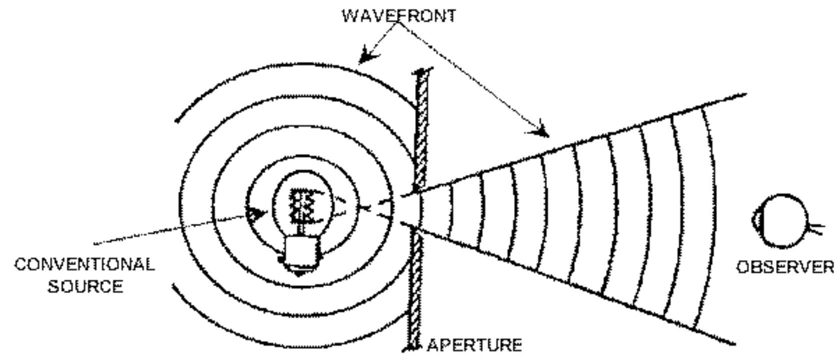
Basic Laser Principles

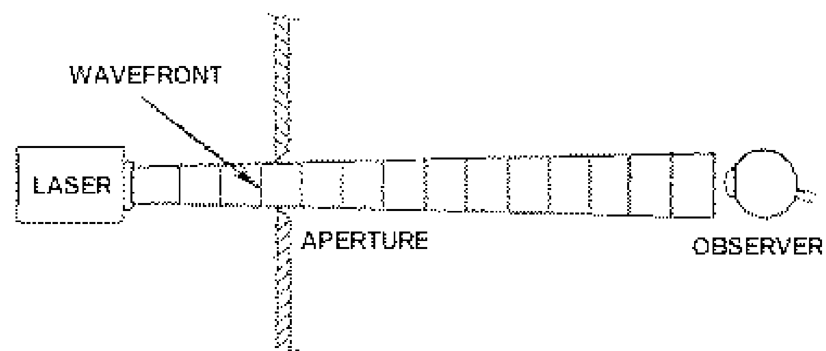
- Laser light is a form of electromagnetic radiation that carries energy and momentum which may be imparted when it interacts with matter.

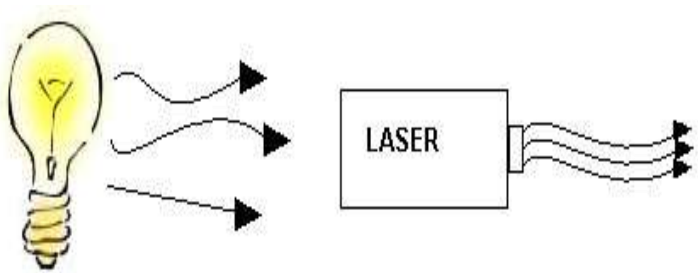


Basic Laser Principles: Light Output

- Laser Light Source
  - Intense
  - Monochromatic
  - Directional
  - Coherent

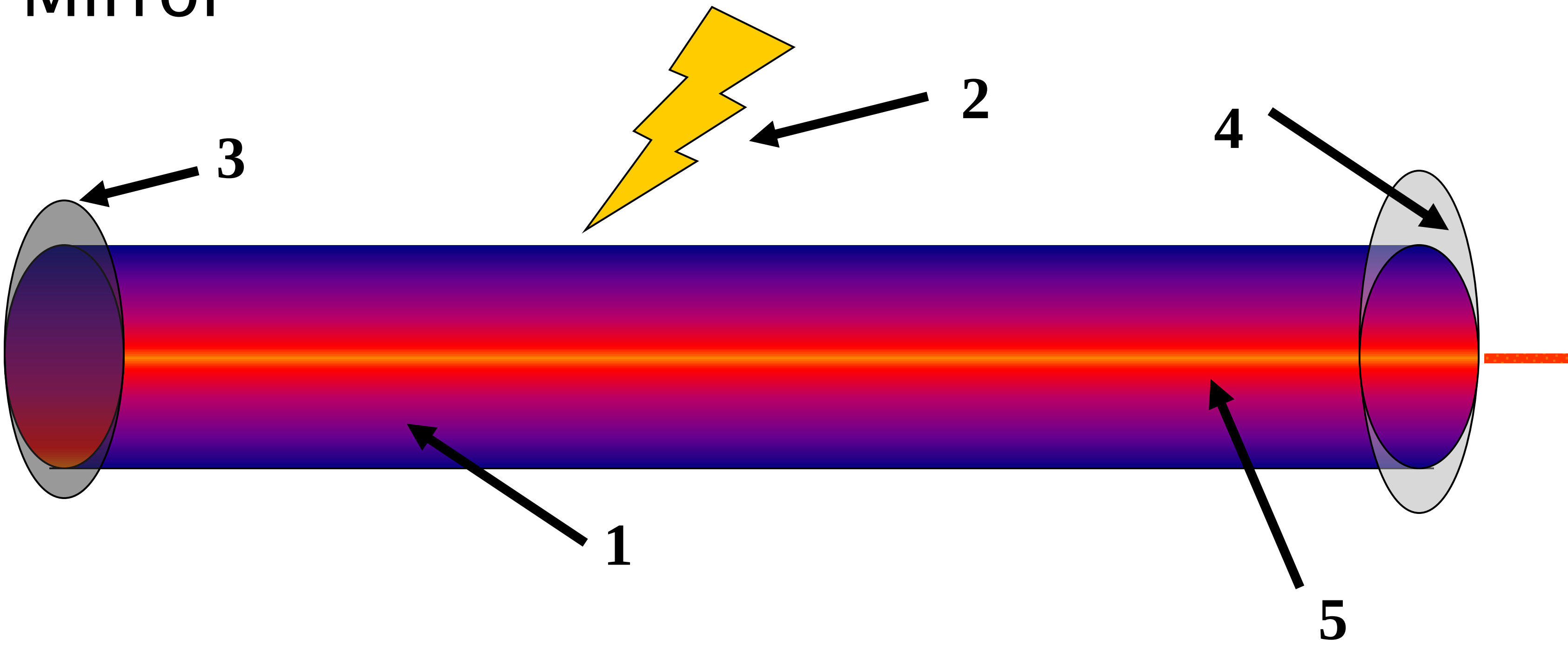






Principle Components

1. Active laser medium
2. Laser pumping energy
3. Mirror
4. Partial mirror
5. Laser Beam



Types of Laser Media

The differences depend on the type of active medium used.

- Gas
- Solid
- Semiconductor/Diode
- Dye
- Excimer

Types of Lasers

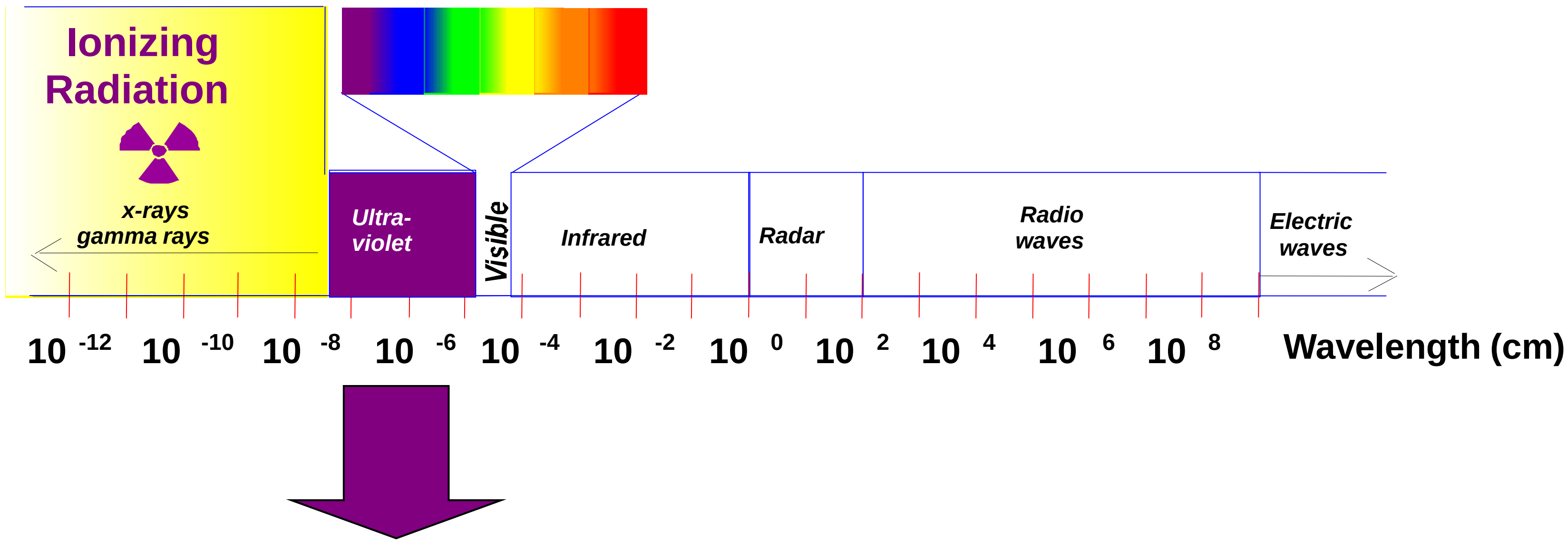
Lasers can be described by:

- which part of the electromagnetic spectrum is represented:
  - Infrared
  - Visible Spectrum
  - Ultraviolet
- the length of time the beam is active:
  - Continuous Wave
  - Pulsed
  - Ultra-short Pulsed

http://www.safety.vanderbilt.edu/training/laser/laser_safety.pps

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

http://www.safety.vanderbilt.edu/training/laser/laser_safety.pps

Common Visible Light Lasers

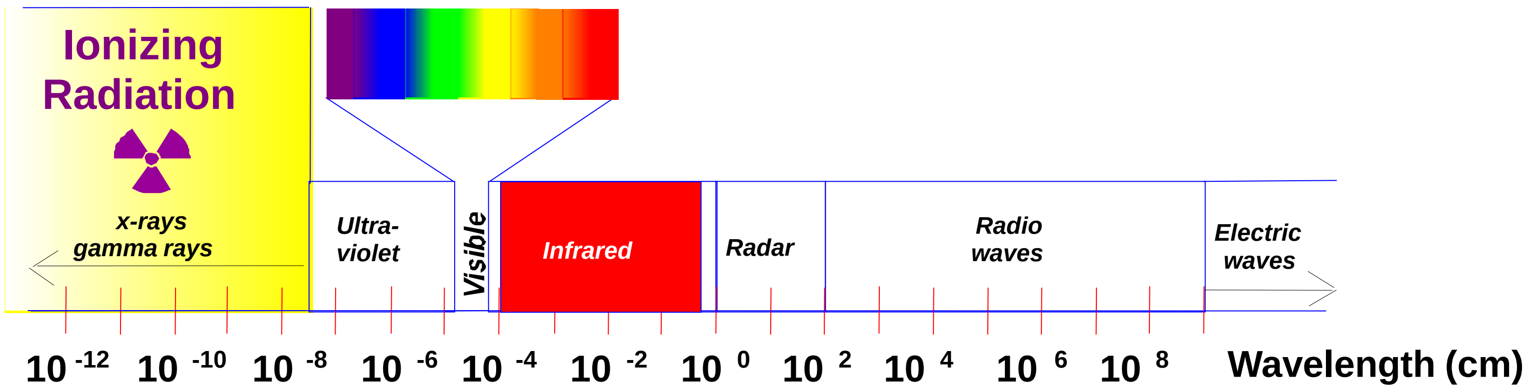
Violet	Helium cadmium	441 nm
Blue	Krypton	476 nm
	Argon	488 nm
Green	Copper vapor	510 nm
	Argon	514 nm
	Krypton	528 nm
	Frequency doubled Nd YAG	532 nm
	Helium neon	543 nm
Yellow	Krypton	568 nm
	Copper vapor	570 nm
	Rohodamine 6G dye (tunable)	570 nm
	Helium neon	594 nm
Orange	Helium neon	610 nm
Red	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.

http://www.safety.vanderbilt.edu/training/laser/laser_safety.pps

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

http://www.safety.vanderbilt.edu/training/laser/laser_safety.pps

Active Beam Time

- Continuous Wave – laser output is steady (output = watts)
- Pulsed (output = energy)
- Q-switched - laser pulse duration is extremely short (nanoseconds)

Dangers associated with the use of lasers

- Beam/Reflection hazards
  - eye damage
  - skin damage
- Non-beam hazards
  - electrical hazards
  - toxic/carcinogenic laser dyes
  - hazardous gases (e.g. excimer lasers)
  - fire

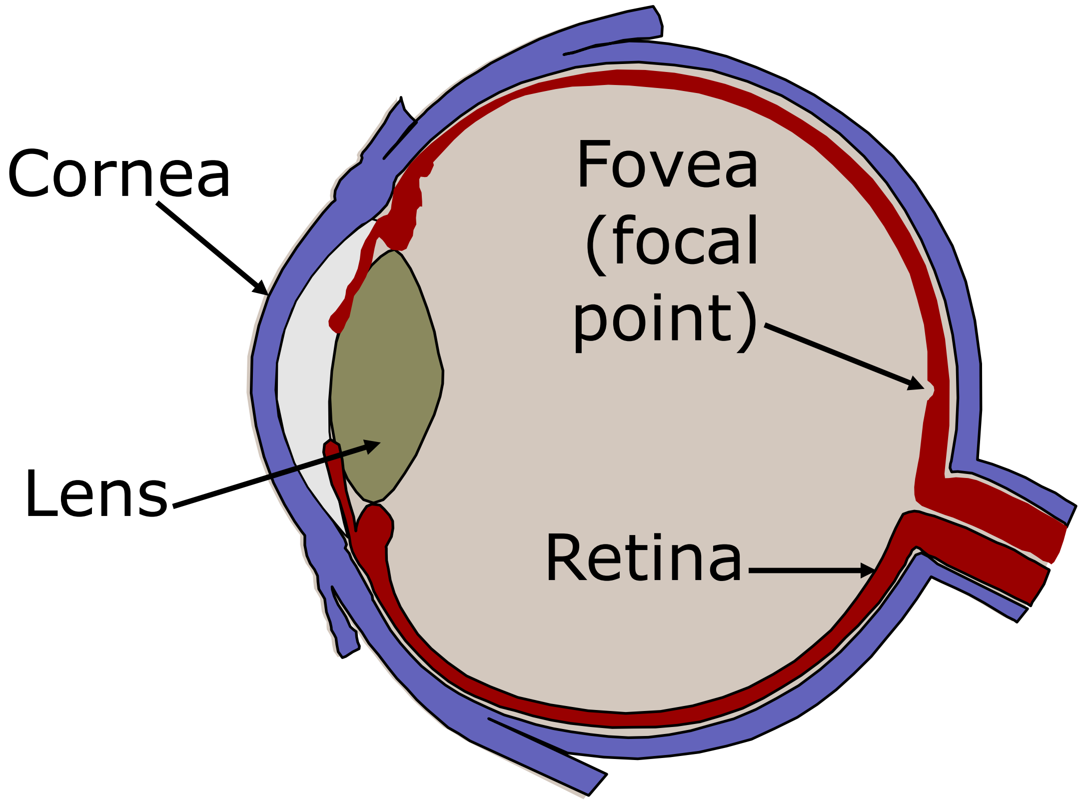
Types of Beam Exposures

- 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.*

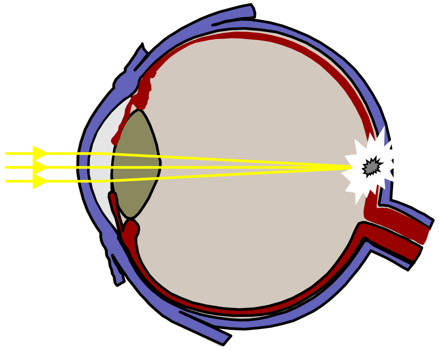
Biological Damage

- Biological damage caused by lasers is produced through
- thermal,
- acoustical and
- photochemical processes

Biology of the Eye



Retinal Hazard Region



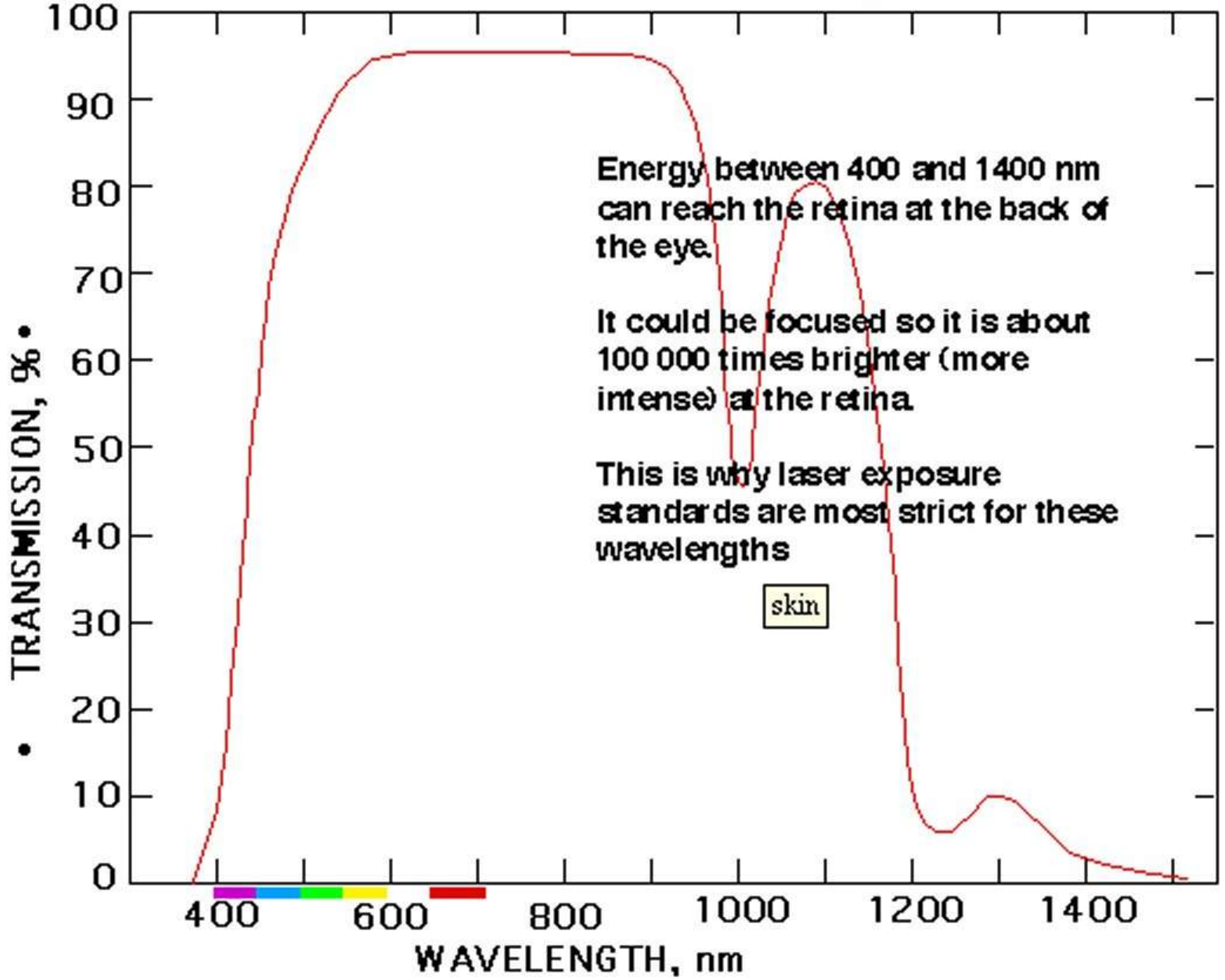
The wavelength range of light that can enter the eye is 400 to 1400 nm, though the range that we can actually see is only 400 – 760 nm.

The eye can focus a collimated beam of light to a spot 20 microns in diameter on the retina (called the *focal point*).

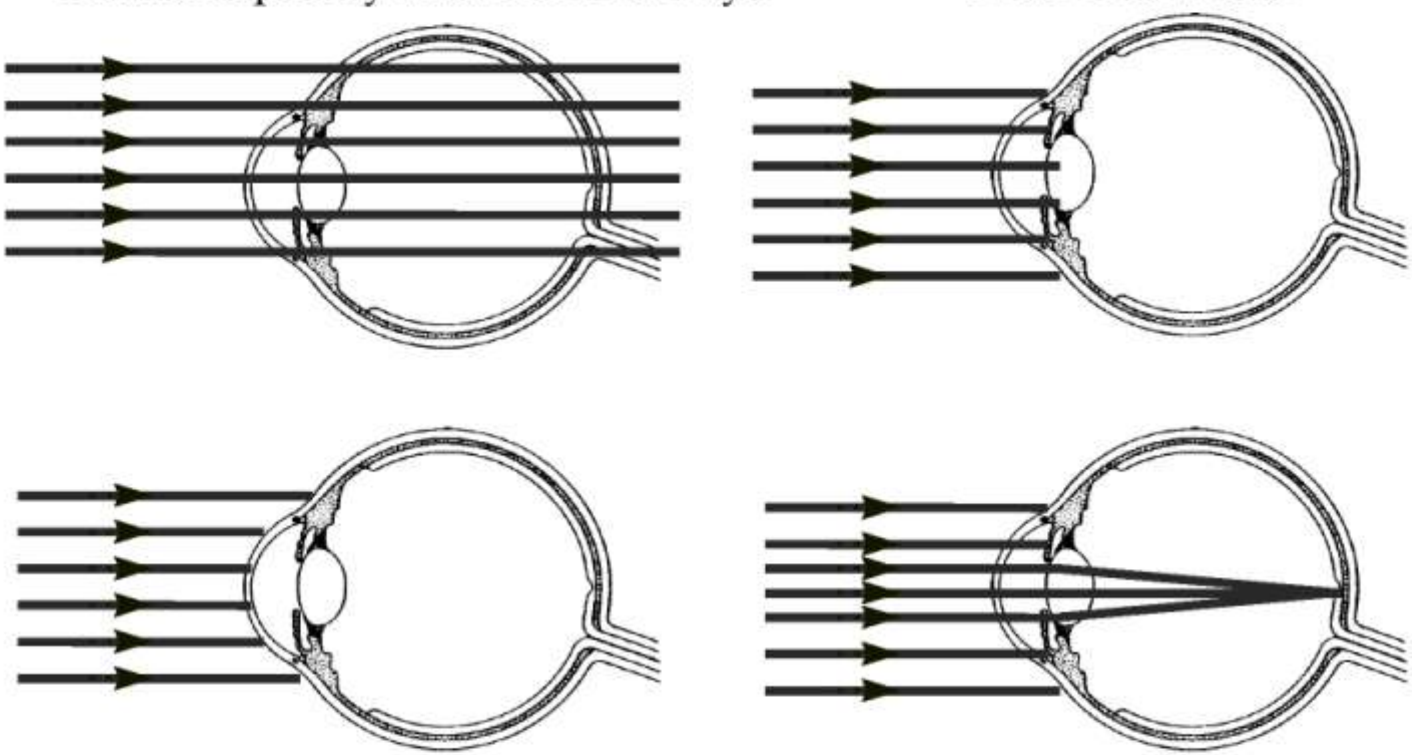
This focusing ability places the retina at risk when exposed to laser light in the wavelength range that will penetrate to the retina, because even fairly low wattage laser light can impact the retina with 100,000 times the radiant power that entered the eye. Because of this optical gain, laser light 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.

Sensitivity to damage: eye transmission



Effect of laser beam depends strongly on wavelength



- Radiofrequency and Gamma Rays
- Near Ultraviolet
- Far Ultraviolet and Far Infrared
- Visible and Near Infrared

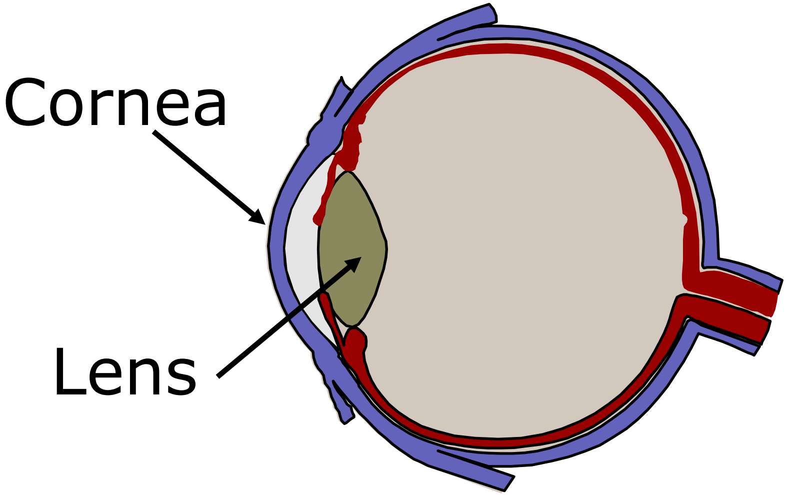
Example of eye injury

Figure 7. Multiple small laser burns with minimal hemorrhage.

Experience has demonstrated that most laser injuries go unreported for 24–48 hours by the injured person. This is a critical time for treatment of the injury.

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 colspan="2">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><td rowspan="2"></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</td><td rowspan="5">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></td></tr>
<tr><td>Infra-red B
(1,4 μm to 3,0 μm)</td><td>Aqueous flare, cataract, corneal burn</td><td></td></tr>
<tr><td>Infra-red C
(3,0 μm to 1 mm)</td><td>Corneal burn only</td><td></td></tr>
</table>

Some 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
- Equipment malfunction
- Improper methods of handling high voltage
- Available eye protection not used
- Intentional exposure of unprotected personnel
- Lack of protection from non-beam hazards

Some common unsafe practices or 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

Guidelines to help prevent 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 jewellery should 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.

Guidelines to help prevent 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 an authorised laser user of that area

Responsibilities

The Principal Investigator is responsible for the safety of its employees and exercises its responsibility by providing guidelines and periodic control by designated safety personnel.

We all have a personal responsibility to make sure that our working conditions and working habits are safe and in accordance with the guidelines.

Laser Safety Regulations

- Occupational Safety & Health Administration (OSHA)
  - No specific laser safety regulations, but will cite safety issues under the General Duty Clause and will enforce the ANSI standard for laser safety.
- American National Standards Institute (ANSI)
  - ANSI Z136.1

Laser Hazard Classes

The ANSI Laser Safety standard has defined ***Laser Hazard Classes***, which are based on the relative dangers associated with using these lasers.

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 and written Standard Operating Procedures.

Class 4 Lasers

- These high-powered lasers are the most hazardous of all classes.
- Even a diffuse reflection can cause injury.
- Visible and near-IR lasers will 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 and written Standard Operating Procedures.

Laser Safety Officer (LSO)

- The *Laser Safety Officer (LSO)* is someone who has authority to monitor and enforce the control of laser hazards and effect the knowledgeable evaluation and control of laser hazards.
- All Class 3b and 4 lasers must have an LSO.
- The *Primary User* will usually be a faculty member who has primary user authority for the laser in question.

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/cm^2 for continuous wave lasers and in J/cm^2 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.

Optical Density

- The OD (absorbance) is used in the determination of the appropriate eye protection.

OD is a logarithmic function defined by:

$$OD = \log_{10}\left[\frac{H_0}{MPE}\right]$$

Where H_0 is the anticipated worst case exposure conditions (in joules/cm^2 or watts/cm^2) and the MPE is expressed in the same units as H_0.

Exposure limits, Determining OD for Eyeware

- A 4 % reflection from a 2.5 mJ laser pulse in a 2 mm beam, gives an exposure of $(10^{-4}\ J)/(pi\ x\ 0.1^2\ cm^2) = 3.2\ 10^{-3}\ J/cm^2$.
- This exceeds the threshold value of the cornea of about $10^{-7}\ J/cm^2$ by a factor of $3.28x10^4$.
- To be adequately protected against this exposure, protective eyewear must have an optical density (OD) of at least $log_{10}(3.2x\ 10^4) = 4.5$

Optical Density for Particular Lasers

Laser Type/ Power	Wavelength (μm)	OD 0.25 seconds	OD 10 seconds	OD for 600 seconds	OD for 30,000 seconds
XeCl 50 watts	0.308[a]	---	6.2	8.0	9.7
XeFl 50 watts	0.351[a]	---	4.8	6.6	8.3
Argon 1.0 watt	0.514	3.0	3.4	5.2	6.4
Krypton 1.0 watt	0.530	3.0	3.4	5.2	6.4
Krypton 1.0 watt	0.568	3.0	3.4	4.9	6.1
HeNe 0.005 watt	0.633	0.7	1.1	1.7	2.9
Krypton 1.0 watt	0.647	3.0	3.4	3.9	5.0
GaAs 50 mW	0.840[c]	---	1.8	2.3	3.7
Nd:YAG 100 watt	1.064[a]	---	4.7	5.2	5.2
Nd:YAG (Q-switch)[b]	1.064[a]	---	4.5	5.0	5.4
Nd:YAG[c] 50 watts	1.33[a]	---	4.4	4.9	4.9
CO_2 1000 watts	10.6[a]	---	6.2	8.0	9.7

[a] Repetitively pulsed at 11 Hertz, 12 ns pulses, 20mJ/pulse; [b] OD for UV and FIR beams computed using 1 mm limiting aperture which presents a "worst case scenario. All visible/NIR computation assume 7 mm limiting aperture.; [c] Nd:YAG operating at a less common 1.33 μm wavelength.; NOTE: All OD values determined using MPE criteria of ANSI Z-136.1

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.
- Can be determined by

$$NHZ = \frac{1}{\phi}\left[\left(\frac{4\Phi}{\pi * MPE}\right)^{1/2} - a\right]$$

- 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.

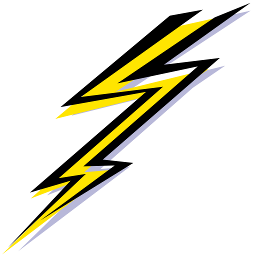
Non-Beam Hazards

Non-beam hazards refer to anything other than the laser itself that can create a hazard. This type of hazard includes:

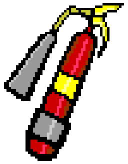
- Electrical Hazards
- Fire Hazards
- Laser Generated Air Contaminants (LGAC)
- Compressed Gases
- Chemical Hazards
- Collateral and Plasma Radiation
- Noise

Non-Beam Hazards – Electric Shock and Fire

- **Electric Shock**
  Use caution when working on or near the high-voltage power supplies used for high-power Class 3 and 4 lasers; there is sufficient voltage in these power supplies to injure or kill.



- **Fire**
  High powered Class 4 lasers will easily ignite flammable materials (such as paper or flammable liquids). You *must* have a fire extinguisher if you have a class 4 laser. In some circumstances, Class 3 lasers could also ignite flammable liquids.



Laser Generated Air Contaminants (LGAC)

- Air contaminated due to interaction of laser beam with target material can result in the production of toxic chemicals.
- During surgical procedures, biohazardous aerosols containing bloodborne pathogens are created.
  - The OSHA web site provides information on biohazardous air contaminants produced during surgery.
  - To prevent personnel from inhaling the LGAC and to prevent the release of LGAC to the environment, exhaust ventilation with special filters may be needed.
- If you are concerned that hazardous air contaminants may be generated by your laser, contact EHS.

Chemical Hazards

Lasers use a variety of lasing mediums, and some of these are comprised of toxic chemicals, such as dyes, solvents and hazardous gases.

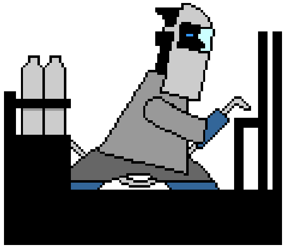
- Many laser dyes and solvents are toxic and carcinogenic.
- A few of the hazardous gases which may be part of your lasing system include chlorine, fluorine, hydrogen chloride and hydrogen fluoride. *Please contact the RMS Chemical Safety Officer for assistance with the special ventilation precautions required for these gases.*
- As with all hazardous chemicals, you should review the Material Safety Data Sheet (MSDS) for the chemicals which are used in or around your laser. Please take the *Safety & Environmental Protection in the Chemical Laboratory* course if you are using hazardous chemicals in your lab.

Compressed Gases

Please take the *Lab Safety Course on Compressed Gas Safety* if you are working with laser systems which utilize compressed gases.

Collateral & Plasma Radiation

- *Collateral radiation* refers to radiation that is not associated with the primary laser beam. This collateral radiation may be produced by power supplies, discharge lamps and plasma tubes. This radiation can be any type of EM radiation, from x-rays to radio waves.
- High powered lasers can also produce *Plasma Radiation* from the interaction of the laser beam with the target material, especially when these lasers are used to weld metals. Plasma radiation may contain enough UV and/or blue light to require additional protective measures.



Noise

- Noise generated by the laser system that is at 90 decibels or higher requires hearing protection.
- If you have reason to believe that your laser is creating a hearing hazard during operation, RMS can perform noise level monitoring to determine whether or not the noise associated with your laser is at this level.

Non-Beam Hazards - Chemicals

Hazardous chemicals used as part of the lasing medium can create special problems.

- Dyes and solvents used in dye lasers are toxic and often carcinogenic and therefore must be handled with care. Make sure laser operators are familiar with the Material Safety Data Sheets for these chemicals.
- Toxic gases, such as HF and halogens commonly used for excimer lasers, will require special cabinets and air handling to prevent exposure to laser operators and release of toxic gases to the environment.

Control Measures

- There are several measures that can be taken to prevent injury from lasers. These measures 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 and are designed to prevent injury to personnel. Engineered safety controls are 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)

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)* which are enforced by the Laser Safety Officer.
- 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.

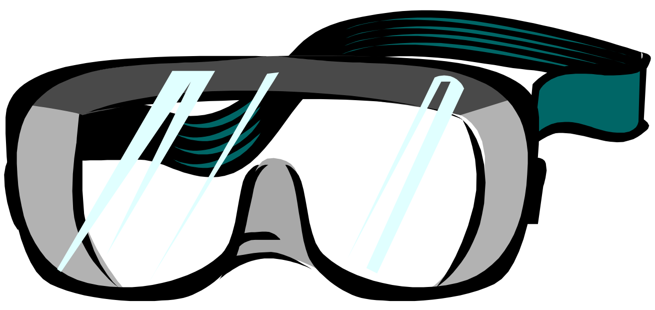
PPE for Skin

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.

PPE for Eyes

- PPE is not required for class 2 or 3a lasers unless intentional direct viewing > 0.25 seconds is necessary.
- Personnel Protective Equipment (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 PPE

PPE may also be required to provide protection from hazardous chemicals and gases. Consult with RMS if you need assistance with determining the appropriate PPE for use 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

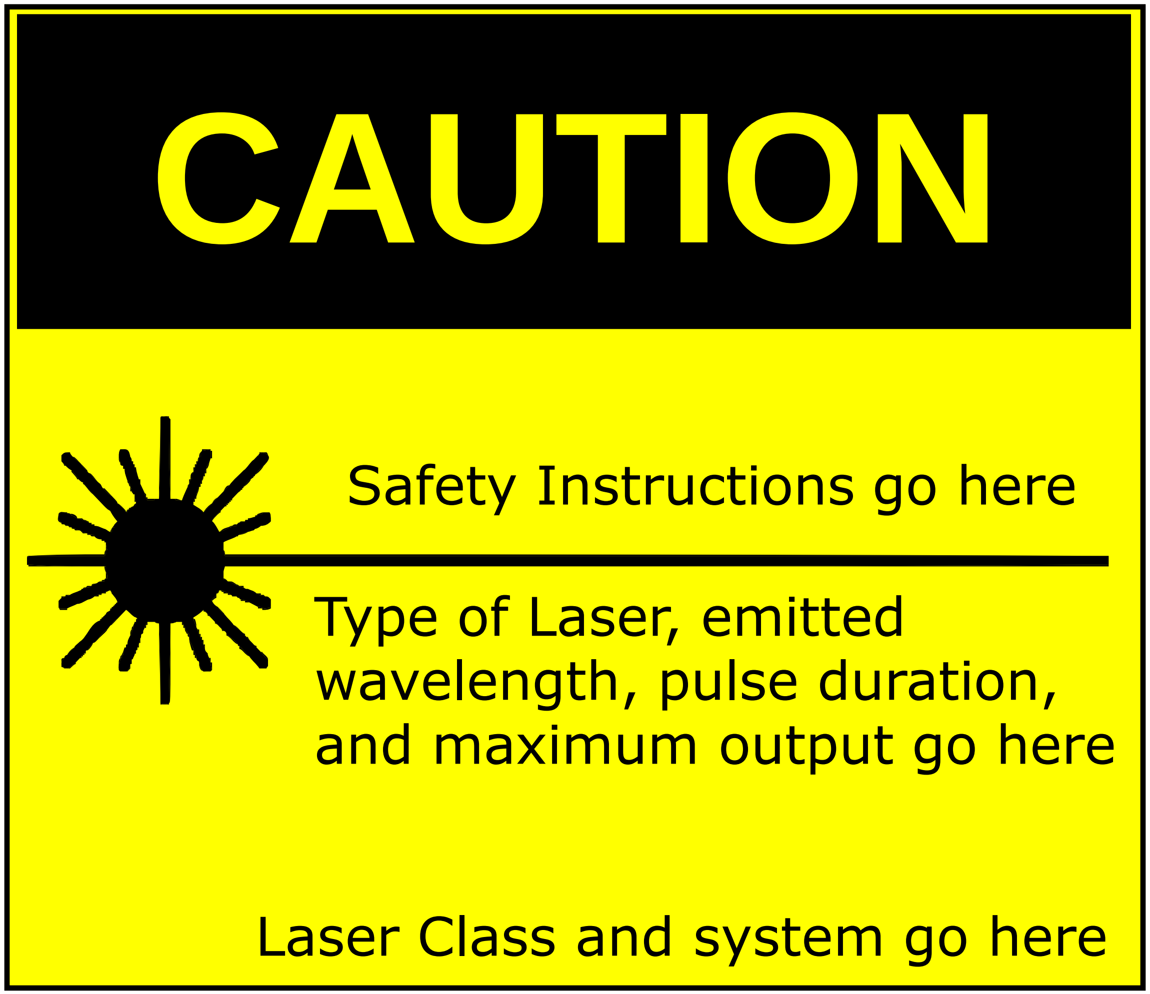
All rooms with class 3a, 3b or 4 lasers must have appropriate signs posted at all entrances. Signs must:

- 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.

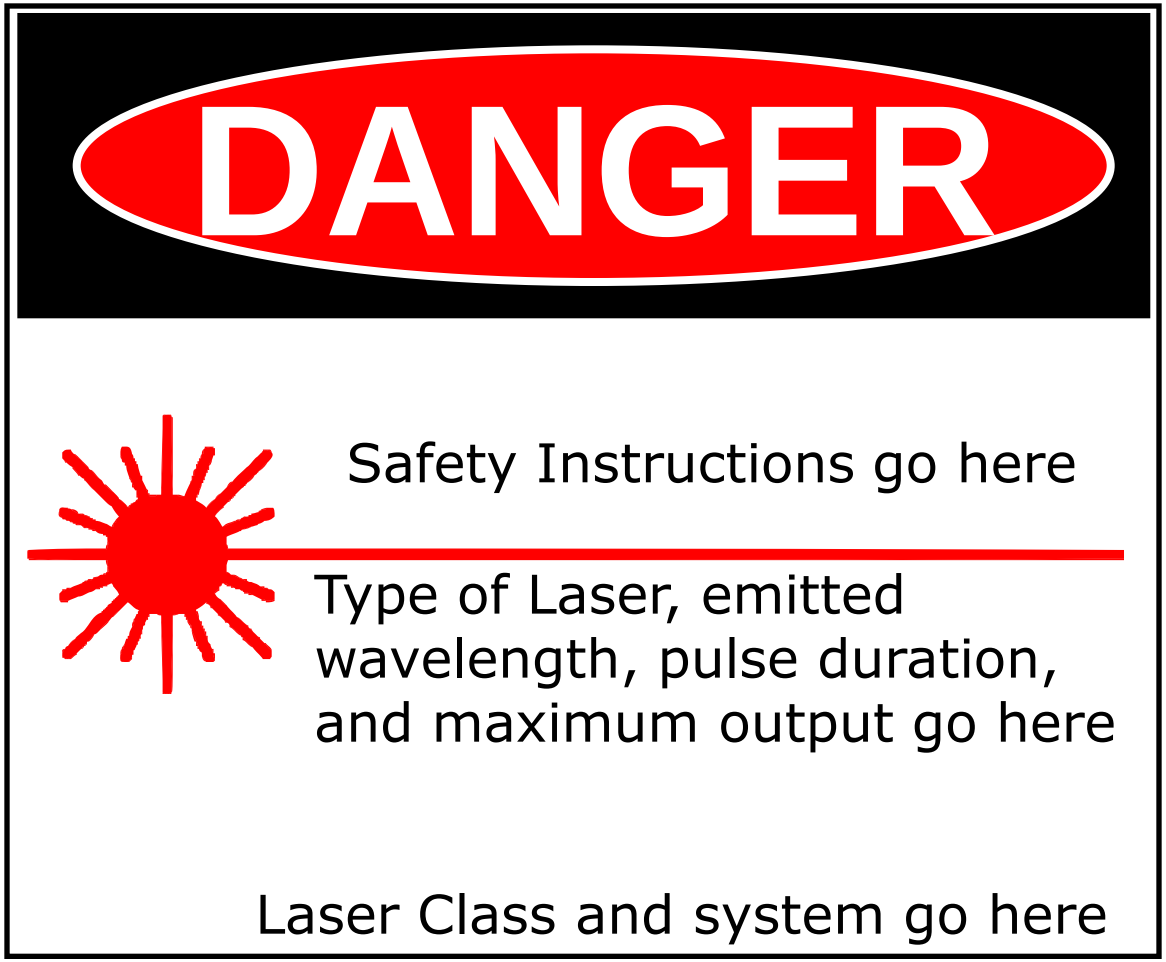
"CAUTION" Warning Sign



Safety Instructions may include:

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

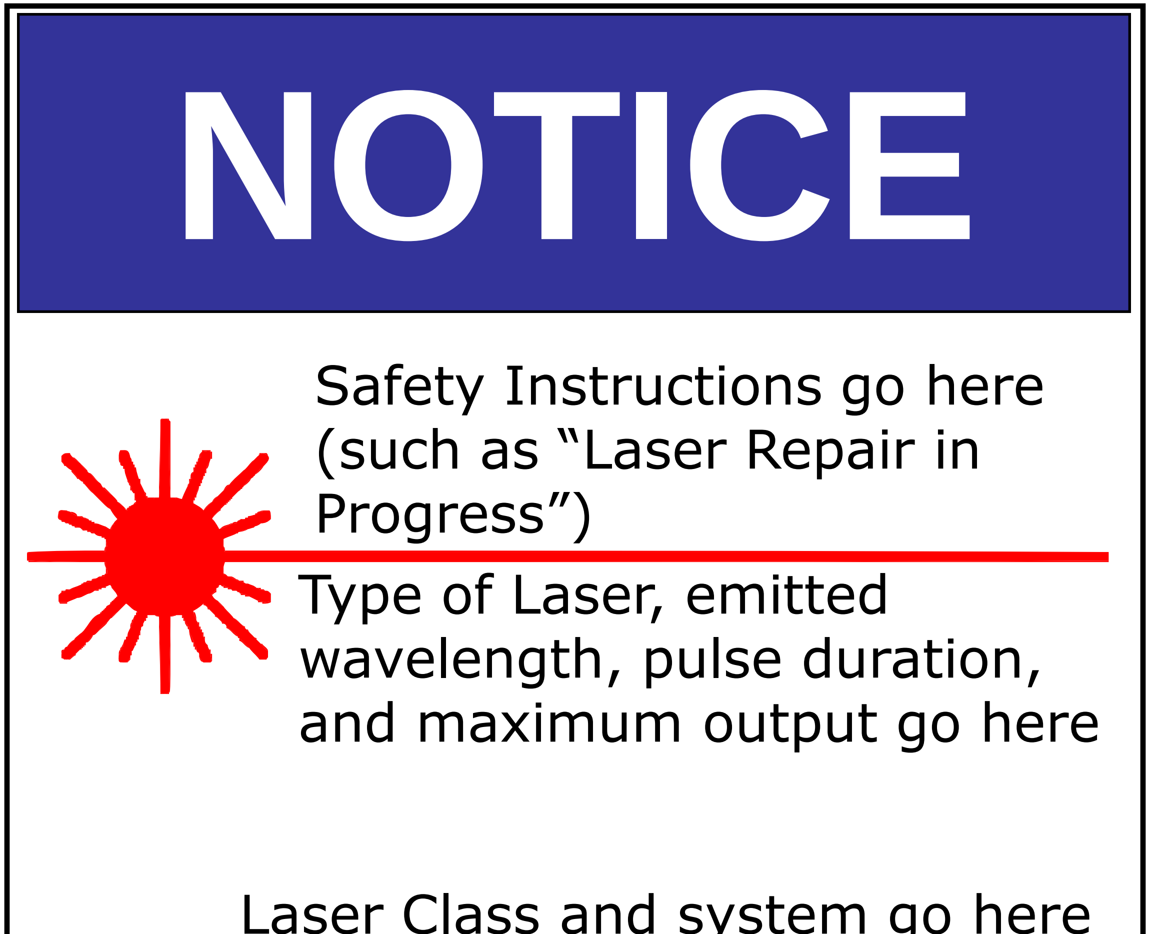
“DANGER” Warning Sign



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 for 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.

Leading Causes of Laser Accidents

- Unanticipated eye exposure during alignment
- Available eye protection not used
- Equipment malfunction
- Improper methods for handling high voltage (This type of injury has resulted in death.)
- Inadequate training
- Failure to follow SOP
- Failure to provide non-beam hazard protection.
- Equipment improperly restored following service
- Incorrect eyewear selection and/or eyewear failure

For More Information

- OSHA Technical Manual – Laser Safety chapter is especially useful
- The ANSI Z136.1 Laser Safety Standard is the best reference to consult for laser safety information.
  - One copy is available for viewing within the EHS administrative offices. (This copy will not be loaned out.)
  - You can also purchase a copy of the standard through the Laser Institute of America web site (http://www.laserinstitute.org).
- Call the Laser Safety Officer at 5-4419 if you have additional questions about laser safety.

Examples of laser accidents

Ancillary Slides, not needed for presentation – but interesting

413 Picosecond pulses cause bleeding/latent viewing distortion

Description:

New frequency doubler didn't have AR coatings as requested. As person left room, beam hit eye corner and transmitted schlera and caused interocular bleeding. Resided at 2 wks and eye normal at 2 months. Person still complains at 8 yrs of floaters and vision that looks "like looking through a dirty window".

Type:FD Nd:YAG
Wavelength:1064 nm
Class:IV
Exposure Time:60 ps

Divergence:-
Energy/Power:MW/cm^2+
Pulse Rate:1 KHz

165 Reflected beam caused vision loss

Description:

Professor from China removed eyewear to "see better" while doing an experiment with a crystal. Exposure produced retinal burn and permanent vision loss. He described seeing a white flash, central purple spot surrounded by yellow halo. No pain reported.

223 Retinal burn from beam off rear laser mirror

Description:

Student *WITH EYEWEAR ON* (and witness to verify) received exposure from the rear mirror of a "Continuum" YAG laser. The student was wearing Glendale Broadband (OD 4.0) eyewear; ANSI standard requires OD=6.0. Retinal burn resulted with permanent damage.

Type:Nd:YAG
Wavelength:532 nm
Class:-
Exposure Time:7 ns

Divergence:-
Energy/Power:0.18/0.40
Pulse Rate:5 KHz

356 Blurred vision from reflected exposure.

Description:

Student received reflected beam from plastic tool box lid from Ti-Sapphire laser. No eye protection worn. Student reported blurred vision and seeing black spots. He was installing a laser transport tube (beam safety tube). The student had not received laser safety training. At 1 month student still had blurry vision.

Type: Ti-Sapphire
Wavelength:800 nm
Class:IV
Exposure Time:120 fs

Divergence:-
Energy/Power:15 mJ
Pulse Rate:10 KHz

312 Off-axis beam causes macular burn in left eye

Description:

Scientist bumped mirror mount in a complex optical array - causing a stray beam to go off-axis. When leaning over the table, he was struck in left eye by beam off lower array mirror. Exam confirmed macular lesion which he states disrupts vision. No eyewear worn and safety knowledge was limited.

Type:Ti-Sapphire
Wavelength:800 nm
Class:IV
Exposure Time:50 ns

Divergence:-
Energy/Power:6 mJ
Pulse Rate:3.3K KHz

307 Backscatter from mirror causes hemorrhage and oveal blindspot

Description:

A 26 year old male Student aligning optics in a university chemistry research lab using a "chirped pulse" Titanium-Sapphire laser operating at 815 nm with 1.2 mJ pulse energy at 1 KHz. Each pulse was about 200 picoseconds.

The laser beam backscattered off REAR SIDE of mirror (about 1% of total) caused a foveal retinal lesion with hemorrhage and blind spot in central vision.

A retinal eye exam was done and confirmed the laser damage.

The available laser protective eyewear was not worn.

283 Photophobia in right eye after beam misalignment

Description:

Received "flash" into eye during alignment where he looked back along the beam path to view reflection off laser face plate. Result caused photophobia with burning sensation. No retinal burns detected. Patient used sunglasses for photophobia.

Type:HeNe
Wavelength:633 nm
Class:-
Exposure Time:~0.25 sec

Divergence:-
Energy/Power:6 mW
Pulse Rate:-

Los Alamos Laser Accident

Description:

A postdoctoral employee received an eye exposure to spectral radiation from an 800 nm Class 4 laser beam. The extremely short pulse (100 fs) caused a 100-micron-diameter burn in the employee's retina. The accident occurred shortly after a mirror was removed from its mount and replaced with a corner cube during a realignment procedure. Although the beam had been blocked during several previous steps in the alignment, it was not blocked in this case. The employee was exposed to laser radiation from the corner cube mount when he leaned down to check the height of the mount. Neither of the two employees performing the alignment was wearing the appropriate laser eye protection. The system had two modes of operation: 10 Hz and 1,000 Hz. In addition, the researcher forgot that the part of the 800 nm beam he could see represented only 1-2% of the beam.

Acknowledgement / References

- This presentation uses slides and information prepared by:
  - http://www.safety.vanderbilt.edu/training/laser/laser_safety.pps
  - http://lf.tnw.utwente.nl/safety/Introduction_Laser_Safety.ppt
  - http://web.princeton.edu/sites/ehs/laserguide/sec6.htm
  - http://en.wikipedia.org/wiki/Laser
- Laser incidents taken from laser accident database of Rockwell Laser Industries, Inc.

  (http://www.rli.com/resources/accident.asp)
- Certain descriptions and numbers are taken from the international standard: IEC 60825-1 Edition 1.2.