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All questions pertaining to this presentation should be directed to Heather Lorenz, Laser Safety Officer.

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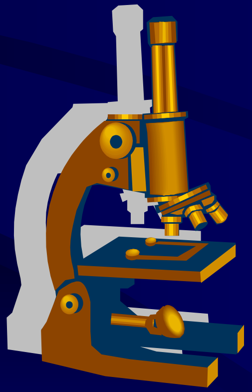
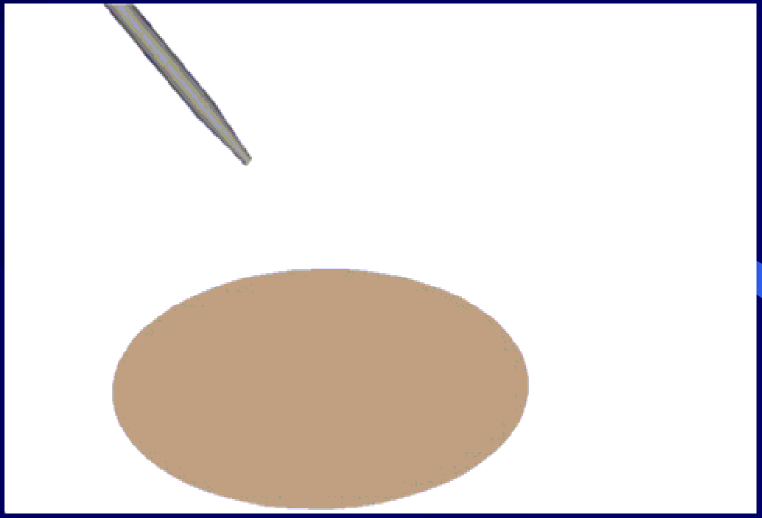
LASER SAFETY

As the use of lasers in research and educational facilities increases the potential for laser accidents also increases.

USES of LASERS

At The University of Toledo, lasers are used in education, research and medical applications.





UNDERSTANDING LASER SAFETY

To understand laser safety the following questions need to be answered:

What is a laser?

What are the potential hazards?

How can these hazards be prevented?

WHAT IS A LASER?

L ight

A mplification by

S timulated

E mission of

R adiation

LASER BASICS

- Laser light differs from ordinary light in 3 ways:

- Monochromatic

- Directional

- Coherent

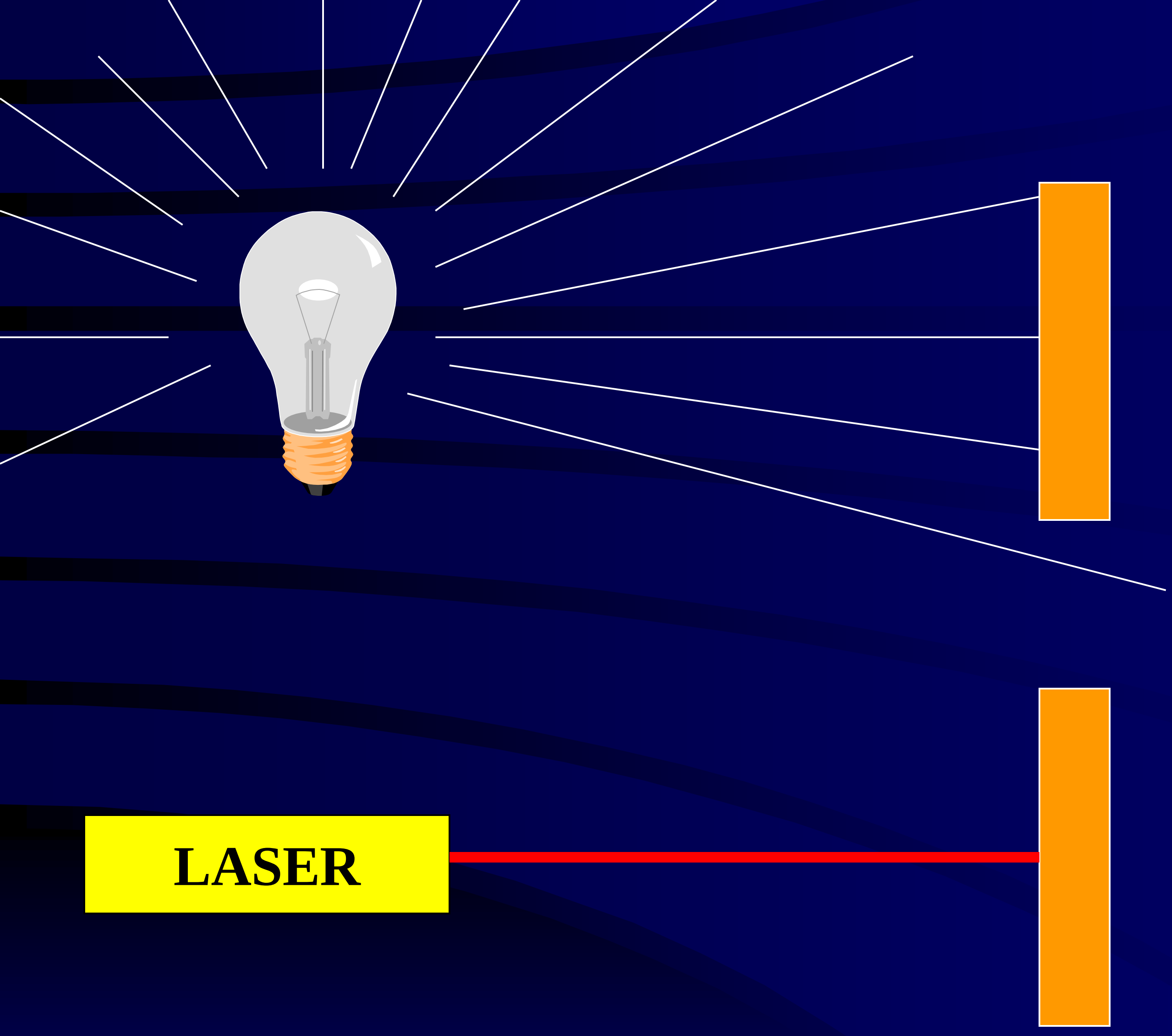
- These three properties allow a laser to focus a lot of energy onto a small area

DEFINITIONS:

Monochromatic - light that is one color or a single wavelength

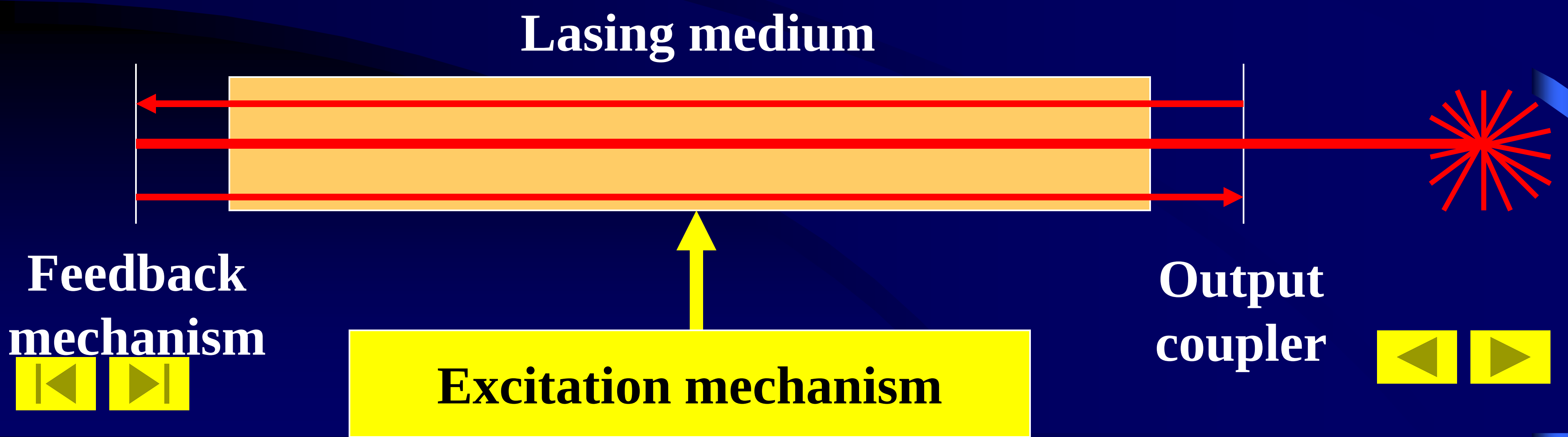
Directional - traveling in one direction from point of origin

Coherent - orderliness of wave patterns by being in phase in time and space


LASER

LASER BASICS -DESIGN

- Lasing Medium (gas, liquid, solid, semiconducter)
- Excitation Mechanism (power supply, flashlamp, laser)
- Feedback Mechanism (mirrors)
- Output Coupler (semi-transparent mirror)



LASER BASICS

Laser Media:

Can be a solid, gas, liquid, or semiconductor.

There are different safety hazards associated with the various laser media.

LASER BASICS

Types of Lasers:

1. **Solid state** lasers
2. **Gas** lasers
3. **Excimer** lasers (a combination of the terms *excited* and *dimers*) use reactive gases mixed with inert gases.
4. **Dye lasers** (complex organic dyes)
5. **Semiconductor** lasers (also called **diode** lasers)

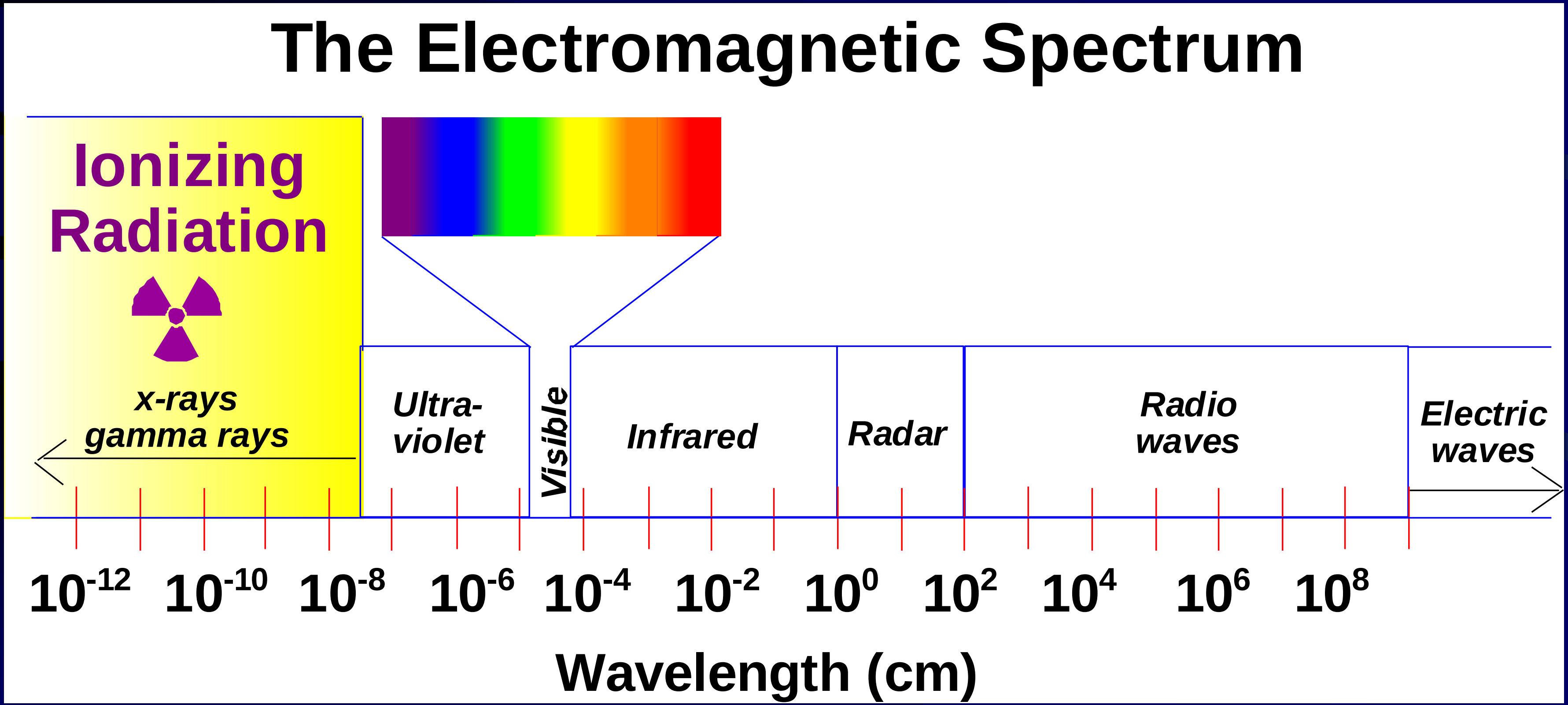
LASER BASICS

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

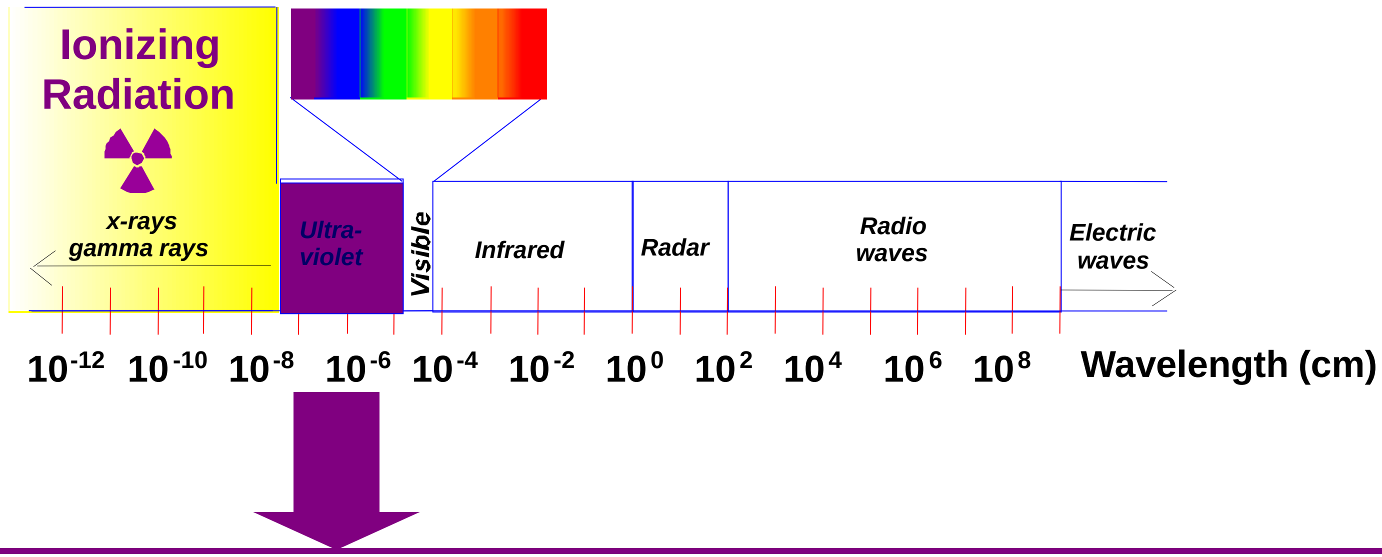
LASER BASICS

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



LASER BASICS

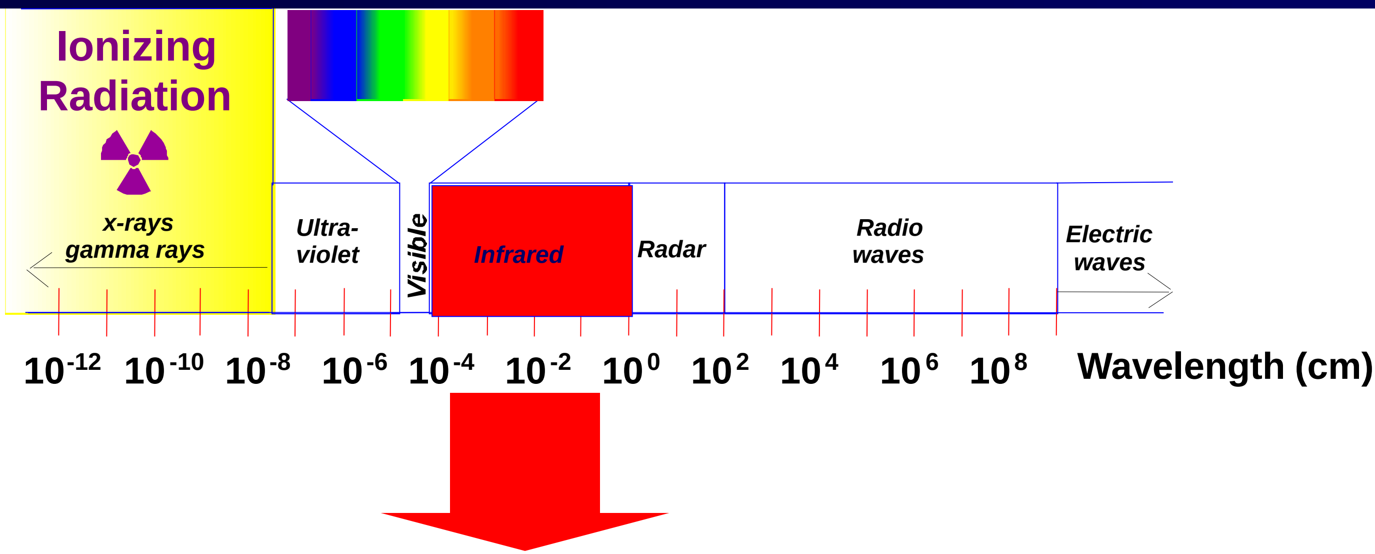
Ultraviolet (UV) lasers range from 200-400 nm.



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

LASER BASICS

Infrared lasers range from 760-10,000 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

LASER BASICS

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 lasers that are *visible* to the eye range from 400-760 nm.

LASER HAZARDS

2 TYPES of hazards:

- Non-beam related

- Beam related effects

NON-BEAM RELATED HAZARDS

Hazards associated with the generation of the laser beam

- **Electrical**
- **Chemical**

NON-BEAM RELATED HAZARDS

- Electrical
    - High voltage – many lasers require high voltage to generate the laser beam
    - Accidental exposure can result in electrical shock or death

- Chemical
    - Dye lasers use hazardous dyes to generate the laser beam
    - These dyes can be toxic or carcinogenic and require proper disposal
    - Contact Safety & Health for information on proper disposal

BEAM RELATED HAZARDS

Hazardous effects related to unintentional direct contact with the laser beam

-Skin related

-Eye related

-Interaction hazards

BEAM RELATED EFFECTS

- Skin related - most skin damage caused by the laser is temporary

- Eye related - eye damage caused by the laser is usually permanent

SKIN RELATED

- Laser effects on tissue are dependent on 4 factors:
  - power density of laser beam
  - wavelength
  - duration of exposure
  - effects of circulation and conduction

SKIN RELATED

-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.

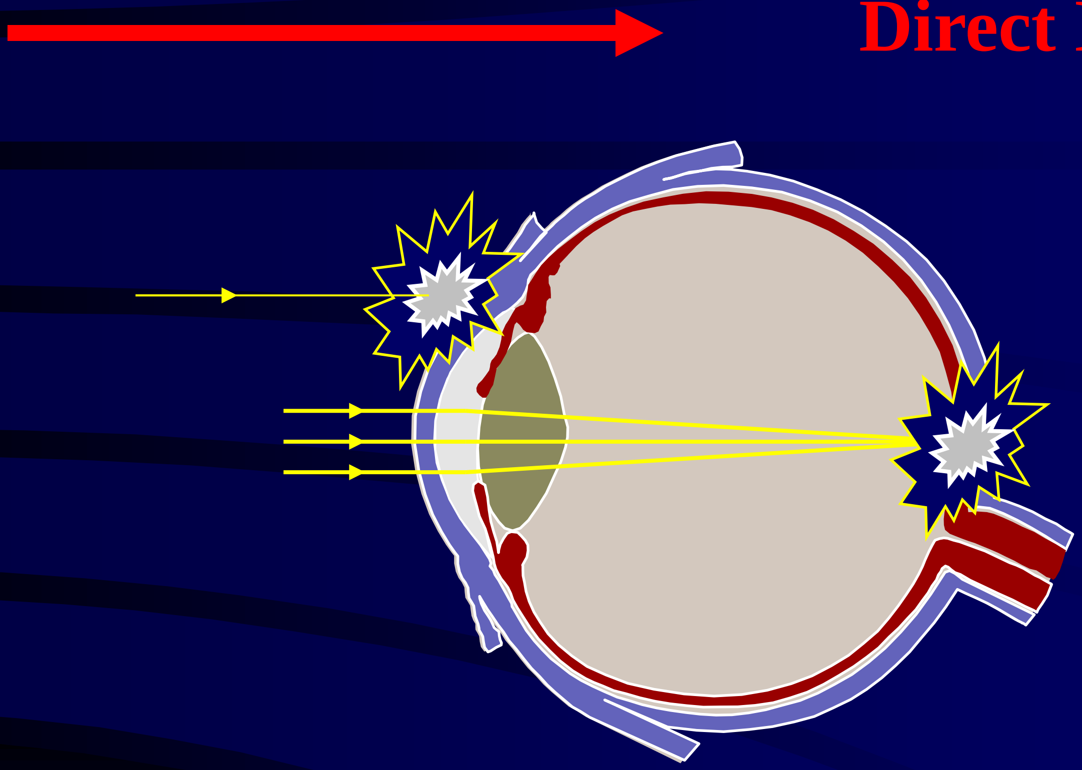
-Thermal burn

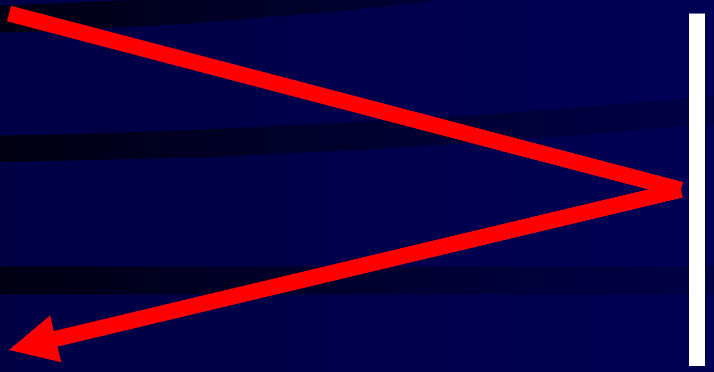
High powered (Class 4) lasers, especially from the infrared (IR) and visible range of the spectrum, can burn the skin.

EYE RELATED

- Injury can result from exposure to:
  - direct beam
  - specular reflection
  - diffuse beam (tissue reflection)
- Damage dependent on:
  - intensity - lens of eye can focus beam onto the retina (dye laser)
  - wavelength - absorbed by different parts of the eye (CO_2 - cornea, sclera)
  - duration - fraction of second, before you can blink

Direct Beam

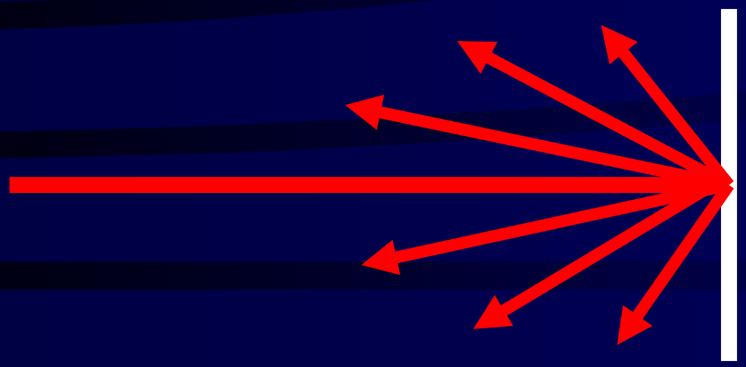




Specular Reflection

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.

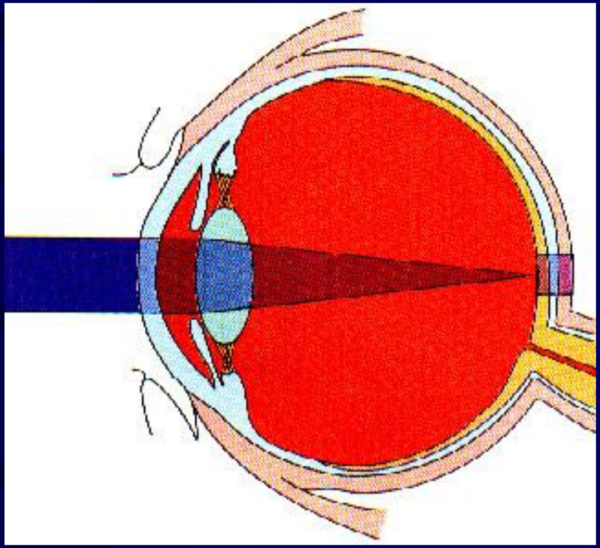
Note that surfaces which appear dull to the eye may be specular reflectors of IR wavelengths.



Diffuse Reflection

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.



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, because even a low power laser 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*.

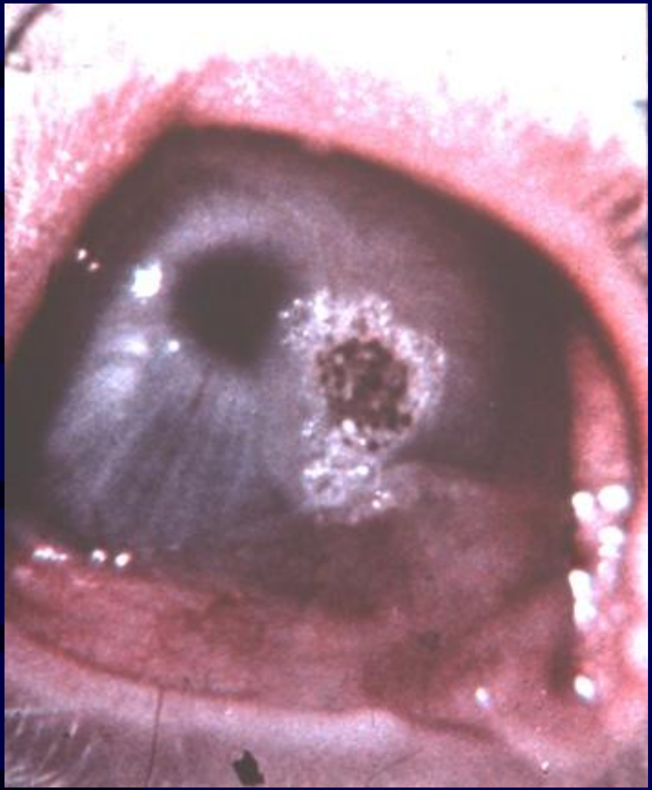
This is important to remember when working with infrared lasers, because the retina can be injured even though the laser is invisible.

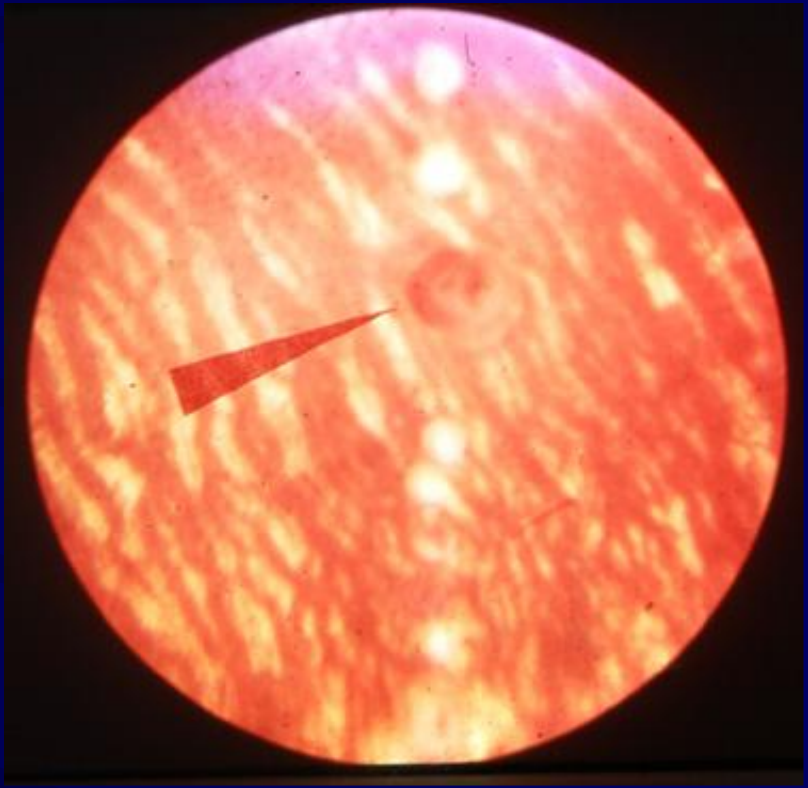
Retinal Injury

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.**





Corneal injury from CO_2 laser

Retinal injury from a dye laser

INTERACTION HAZARDS

- Laser Generated Air Contaminants (LGAC)

- Fire and explosion

- Plasma Radiation

Laser Generated Air Contaminants (LGAC)

-Air contaminated due to interaction of laser beam with target material can result in the production of toxic chemicals.

-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.

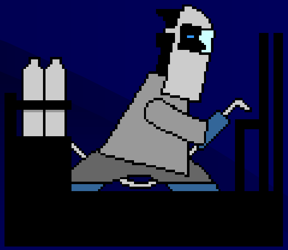
-If you are concerned that hazardous air contaminants may be generated by your laser, contact Safety and Health.

FIRE AND EXPLOSION

Can occur if the laser beam comes into contact with combustible or volatile materials.

PLASMA RADIATION

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.



PREVENTION

- The potential laser hazards discussed must be eliminated or controlled for the safe use of lasers in the educational and research arena.

CONTROL MEASURES

There are 3 basic control measures:

- **Engineering**
- **Personal protection**
- **Administrative**

ENGINEERING

These are control measures that are built into the laser system, such as:

- enclosing the electrical system, within a cabinet

- enclosing the beam within fiber optics or beam tubes

PERSONAL PROTECTION

- Eyewear
- Barriers
- Fire protection
- Smoke evacuation & filtration

EYE PROTECTION

- **Personnel Protective Equipment (PPE) is mandatory for personnel exposed to Class 3b or 4 lasers.**
- **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)**

EYE PROTECTION

Eyewear

- Each laser requires specific eyewear that is capable of absorbing laser light of that specific wavelength

SKIN PROTECTION

Requires the use of Barriers

- **Clothing**
- **Gloves**
- **Sun screen (UV)**

FIRE PROTECTION

High powered Class 4 lasers and some Class 3b lasers will easily ignite flammable materials (such as paper or flammable liquids).

You *must* have a fire extinguisher if you have a class 3b or 4 laser.

SMOKE EVACUATION & FILTRATION

- Air contaminated due to interaction of laser beam with target material can result in the production of toxic chemicals.
- 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 Safety and Health.

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 the room.**
- **Training for all personnel who will be operating the laser or in the vicinity of the laser while it is in operation.**
- **Allow only authorized, trained personnel in the vicinity of the laser during operation.**

UT Procedures & Policies

- Institutional
- Individual Laboratories

STANDARDS

Each PI should develop their own set of operating standards.

An important source of Suggested Standards to be followed is provided by the federal government in the "American National Standards For The Safe Use Of Lasers" and the "American National Standards For The Safe Use Of Lasers In Educational Institutions"


American National Standard
American National Standard
for Safe Use of Lasers
ANSI
American National Standard
American National Standard
for Safe Use of Lasers
in Health Care Facilities
ANSI
American National Standards Institute

Institutional Procedures & Policies

- UT Laser Safety Manual
  - Located on Safety & Health website www.utoledo.edu/depts/safety
  - Educational & research laser use
  - Laser use in UT health care facilities
- Safety Procedure #HM-08-002 – Laser Systems

Procedure #HM-08-002 – Laser Systems

- All Departments/Divisions/Laboratories must have policies & procedures addressing safety precautions for personnel

- **Safety Precautions (based on ANSI)**
  - **Trained personnel to oversee laser operation and laser safety**
  - **Record all activity in a log book & report any incidents**
  - **Insure there is proper laser signage**
  - **PPE (eyewear) worn by all present**
  - **Use of visible alarms (lighted "laser in use" sign)**
  - **Laser key removed after use (also OSHA)**
- **All laser system repairs documented**
- **Rental lasers**
  - **Shall be inspected by Tech Support**
  - **Tech from outside must provide credentials**
  - **Provide record of maintenance & repair**

Laser Safety Manual

- This manual covers the requirements and recommended details that are applicable to all lasers used in research and instructional laboratories, classrooms and lecture halls at the University of Toledo.

PI Responsibilities

- The immediate supervision of lasers in the laboratory.
- Providing, implementing and enforcing the safety recommendations and requirements prescribed in this program
- Completing a Standard Operating Procedure for each laser under his/her control and sending a copy to Safety and Health.
- Completing a specific Standard Operating Procedure for laser demonstrations and sending a copy to Safety and Health.
- Completing Standard Operating Procedures outlining alignment methods for all Class 3B or 4 or Embedded Class 3B or 4 laser systems
- Maintaining hard copies of the Laser Safety Manual and the SOP in the laser work area.
- Keeping a laser log showing periods of use, service, maintenance and incidents.
- Classifying and labeling of each laser under his/her control
- Completing a Laser Inventory Form located on the Safety & Health website for each laser under his/her control and sending it to Safety and Health.

PI Responsibilities

- Updating the laser inventory whenever a new laser is brought into the lab or removed from the lab or decommissioned.
- Notifying the LSO of any inoperable or decommissioned lasers so they can be “Locked Out” and labeled “Do Not Operate”.
- Attending the University's Laser Safety Training program or viewing the on-line Laser Safety power point training and testing module on the Safety & Health Homepage.
- Notifying Safety and Health immediately in the event of an exposure beyond the level of the MPE (Maximum Exposure Limit) to a Class 3 or Class 4 laser.
- Determining the need for personal protection for a particular laser and providing the proper protective equipment

Laser Operator Responsibilities

- Following laboratory administrative, alignment and standard operating procedures while operating lasers.
- Keeping the Principal Investigator fully informed of any departure from established safety procedures. This includes notification of an exposure incident.
- Attending the University's Laser Safety Training program or viewing the on-line Laser Safety power point training and testing module on the Safety & Health Homepage

Laser Safety Survey of all UT Laser Use Areas

- All areas of laser use on all UT campuses will be surveyed by the UT LSO (Laser Safety Officer)
- The survey will take place at least once per year
- The survey questions are based on Institutional Procedures & Policies and the Laser Safety Manual

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

End of Training Session