Laser Safety Training

The University of Texas
Health Science Center at Houston

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Radiation Safety Program
Environmental Health & Safety

Laser Safety Course Objectives

- Explain the Basics of Lasers and Laser Light
- Identify Laser Beam Injuries
- Define the Laser Hazard Classes
- Apply Laser Control Measures

BASICS OF LASERS AND LASER LIGHT

LASER is an acronym for

L ight

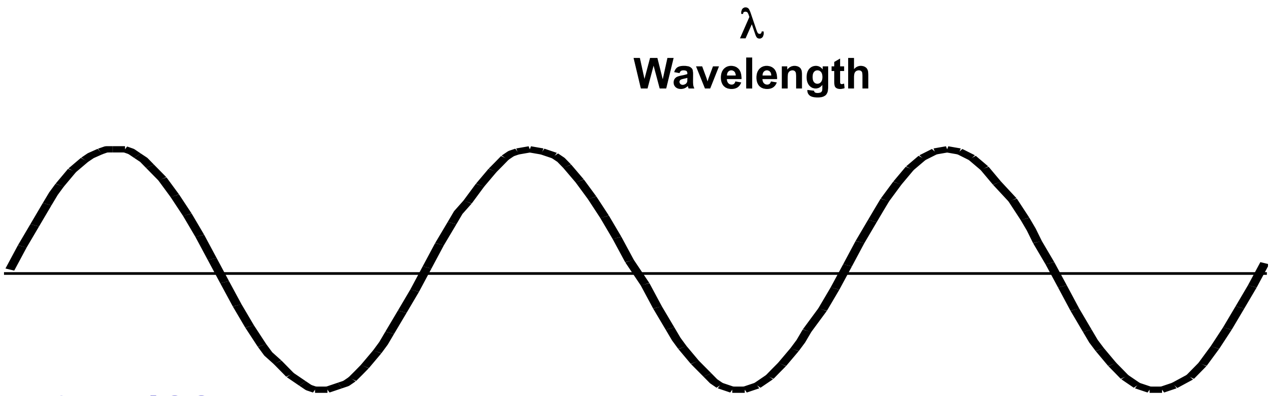
A mplification by

S timulated

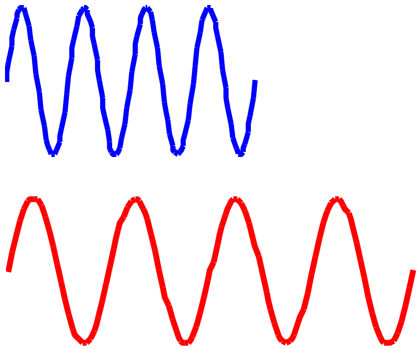
E mission of

R adiation

Light Follows a Wave Nature



Blue: λ = 400 nm

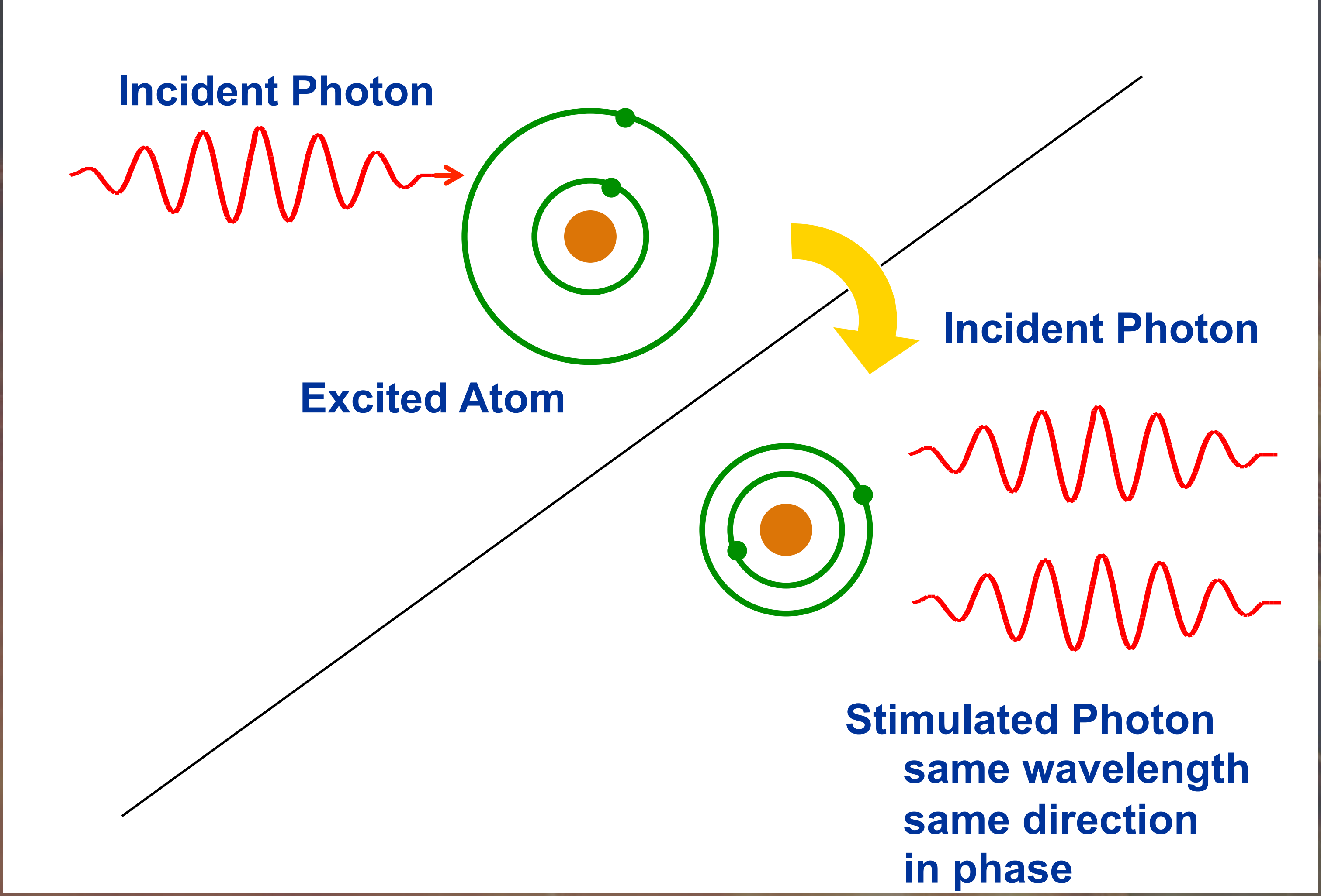


Red: λ = 700 nm

Light is an electromagnetic wave.

Different wavelengths in the visible spectrum are seen by the eye as different colors.

Stimulated Emission of Radiation

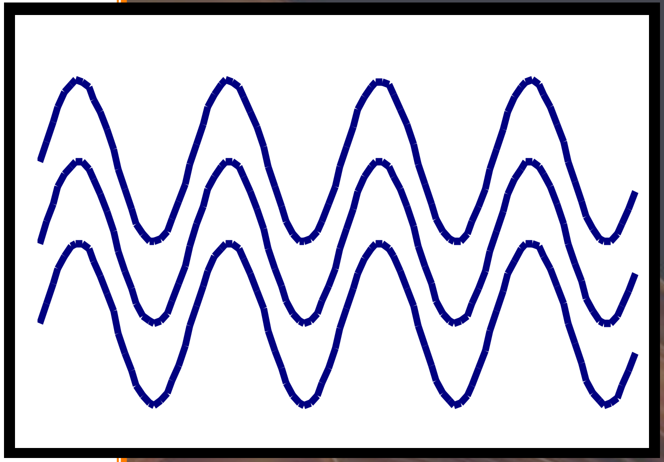


Characteristics of Laser Light

MONOCHROMATIC

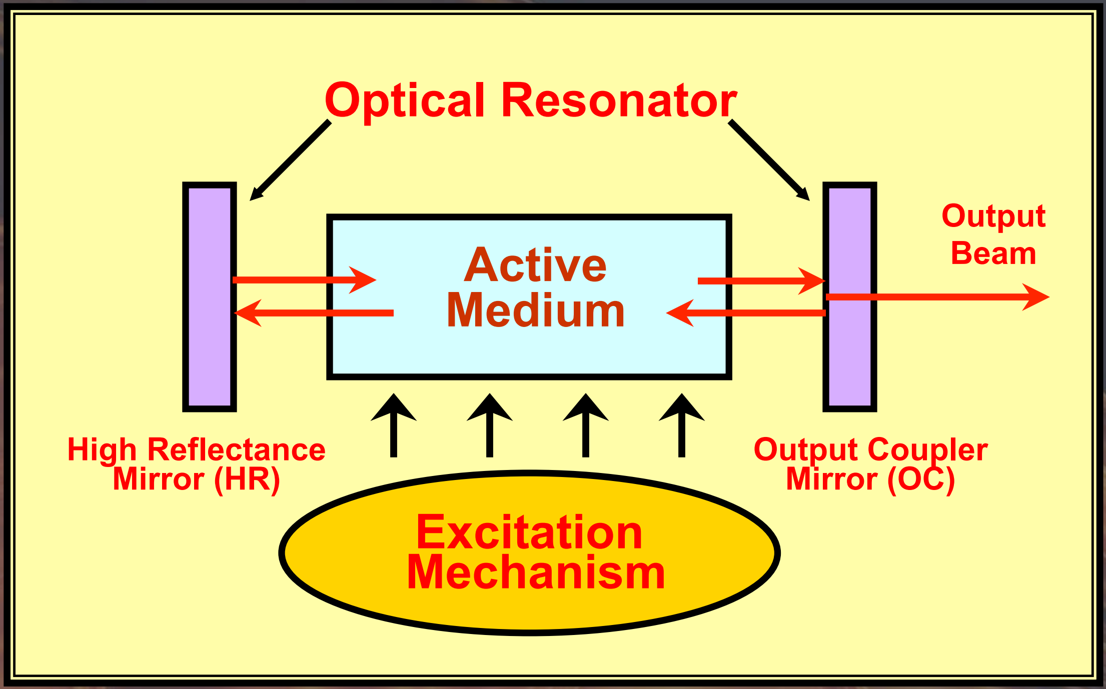
DIRECTIONAL

COHERENT



The combination of these three properties makes laser light focus 100 times better than ordinary light

LASER COMPONENTS



ACTIVE MEDIUM

Solid (Crystal)
Gas
Semiconductor (Diode)
Liquid (Dye)

EXCITATION MECHANISM

Optical
Electrical
Chemical

OPTICAL RESONATOR

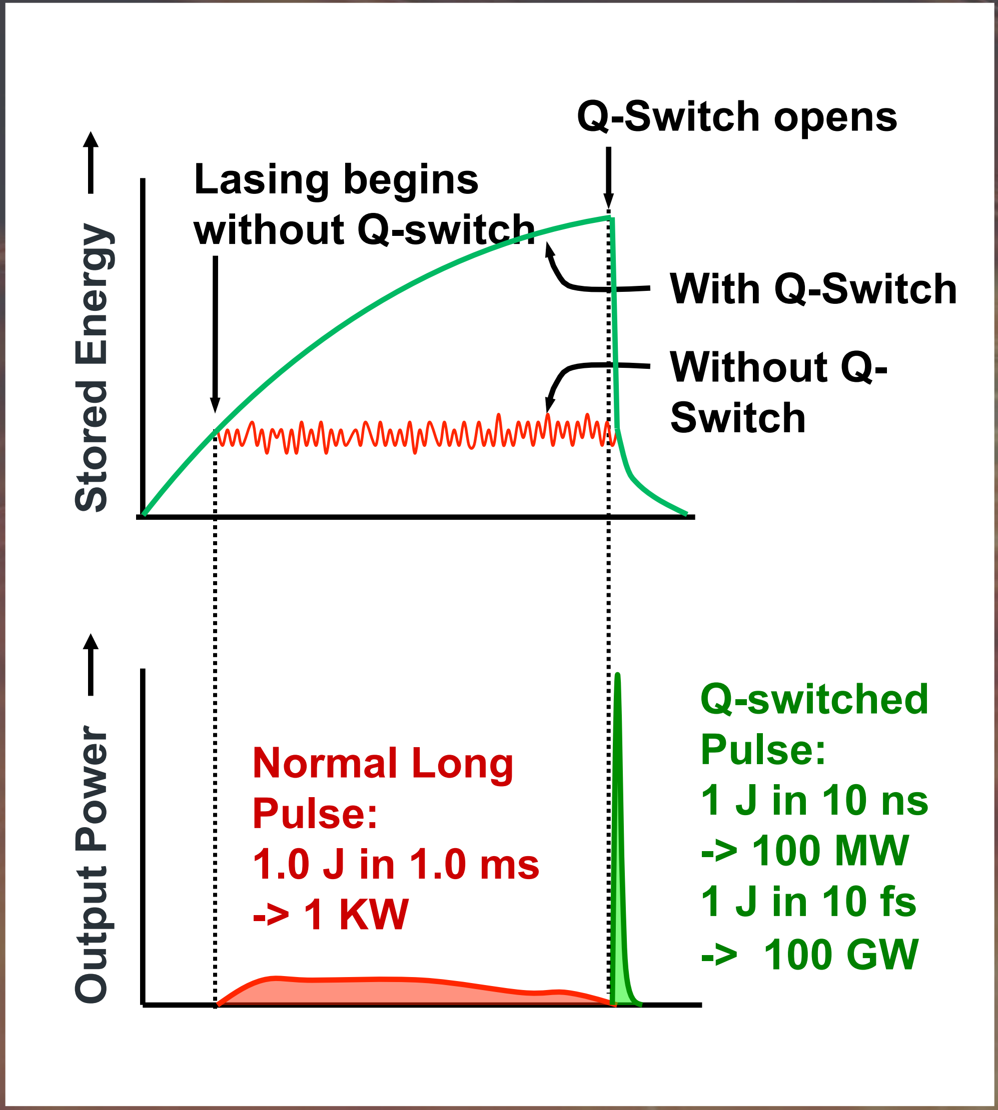
HR Mirror and Output Coupler

The **Active Medium** contains atoms which can emit light by stimulated emission.

The **Excitation Mechanism** is a source of energy to excite the atoms to the proper energy state.

The **Optical Resonator** reflects the laser beam through the active medium for amplification.

FUNDAMENTALS OF Q-SWITCHING

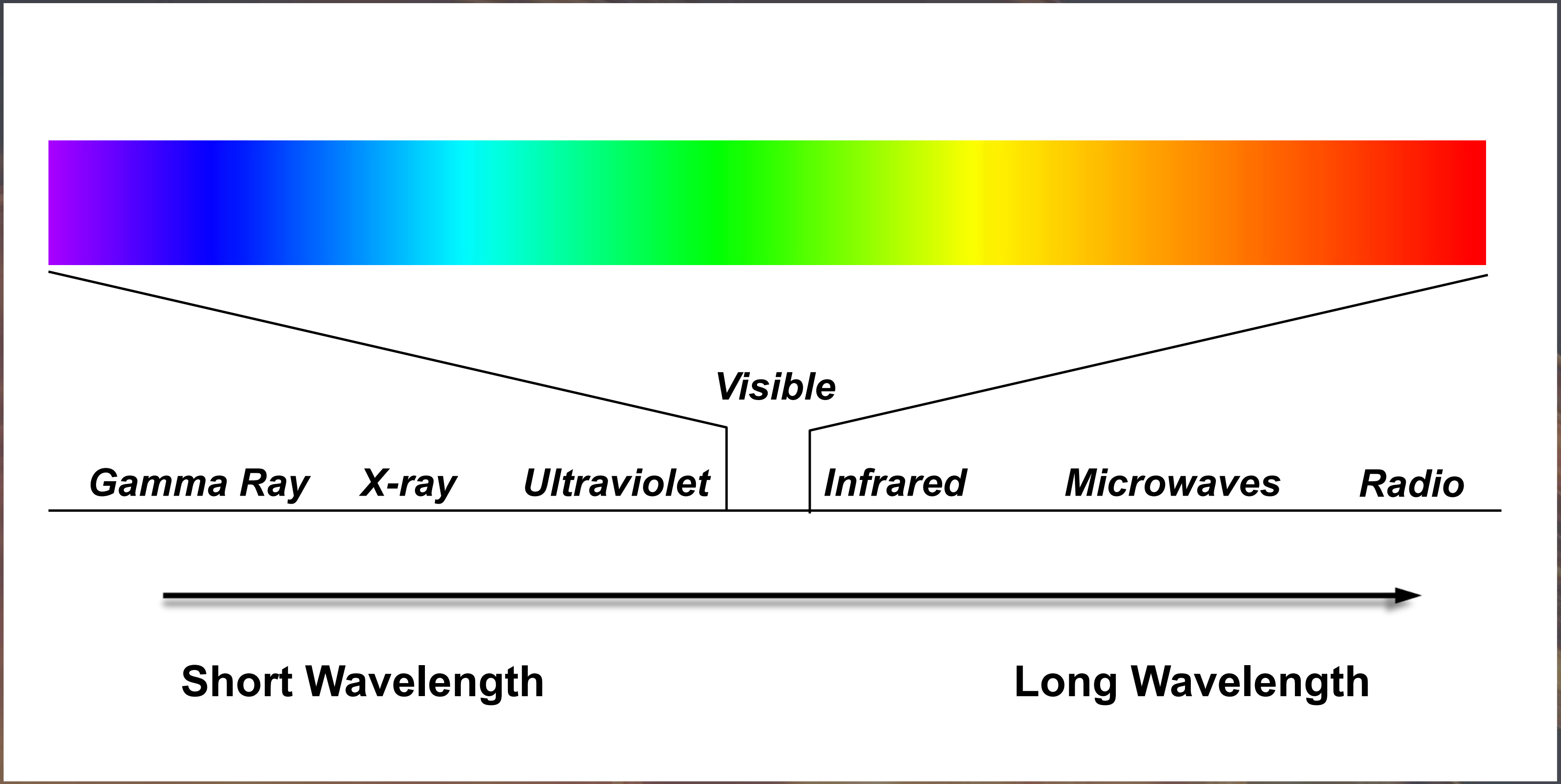


Q-switch is the method in which a laser can be pulsed. Pulsing a laser is essential to some experiment but different hazards can be presented.

Power is measured in units of energy divided by time (J/s). If you decrease the amount of time a certain energy hits a target, the greater the power that hits the target. Simply put, a shorter pulse time is more powerful then a long pulse of the same energy.

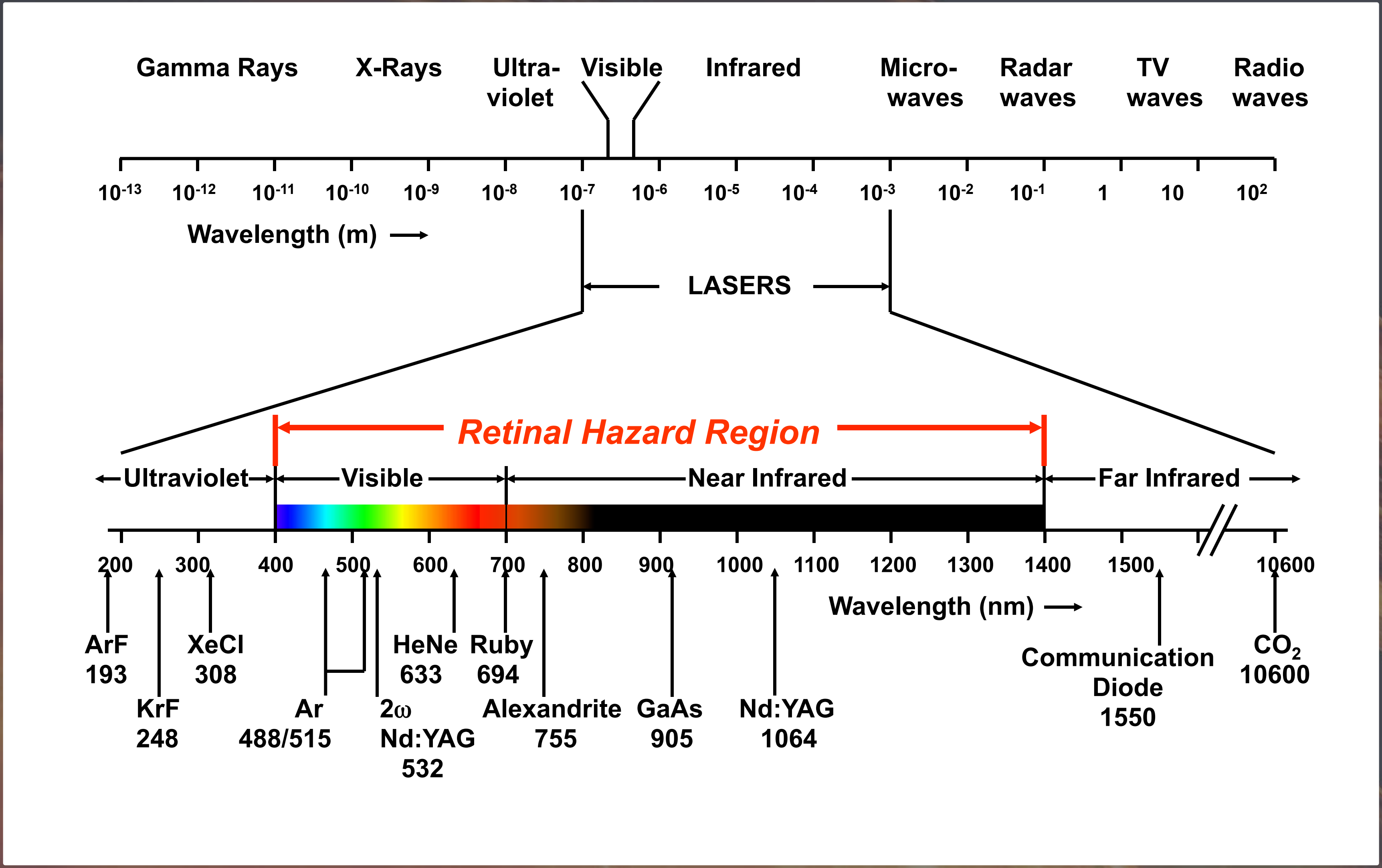
This method could potentially make a laser that incapable of causing harm to become dangerous.

ELECTROMAGNETIC SPECTRUM



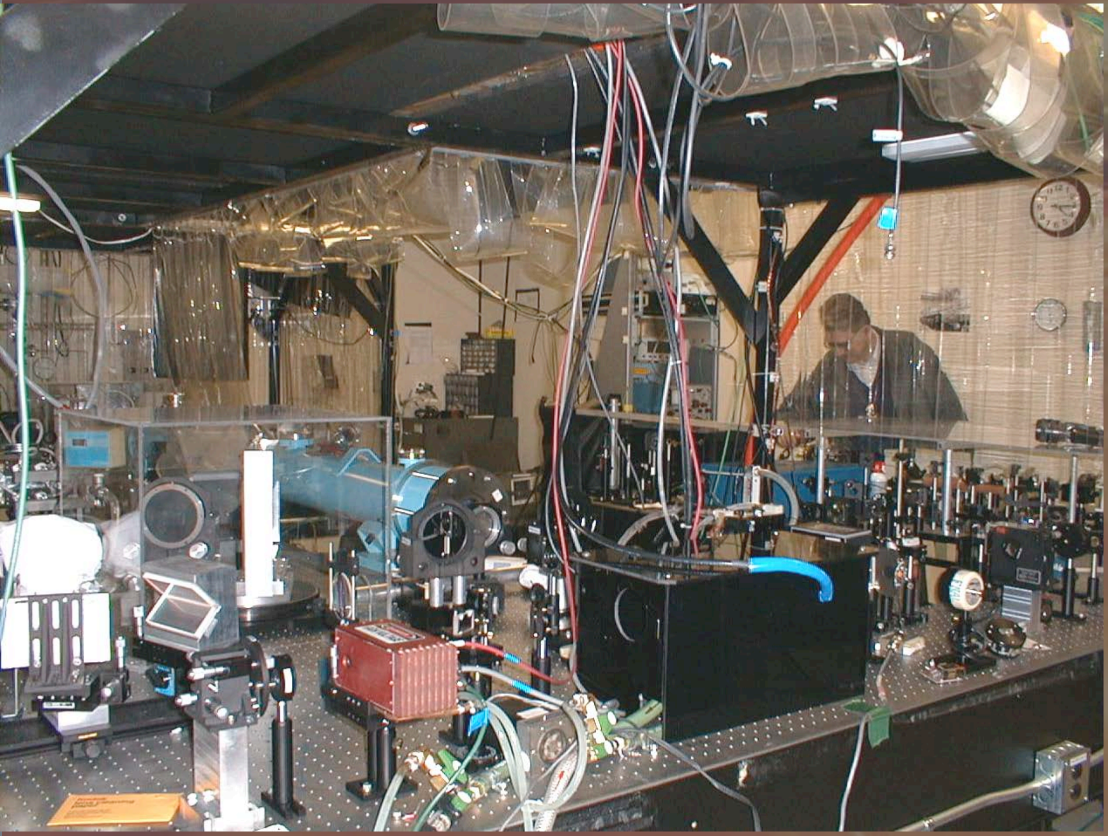
Lasers operate in the ultraviolet, visible, and infrared.

LASER SPECTRUM



Laser Use

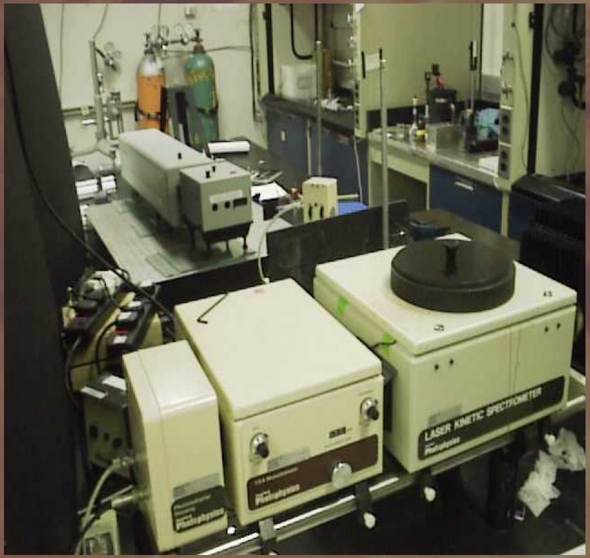
Lasers are used in a multitude of different industrial, medical, and research processes



- **Research**
  - Study of mechanisms at interfaces
  - Detection of single molecules
- **Medical/Dental**
  - Eye surgery
  - Dermotology
  - Reshaping of Teeth and Gums

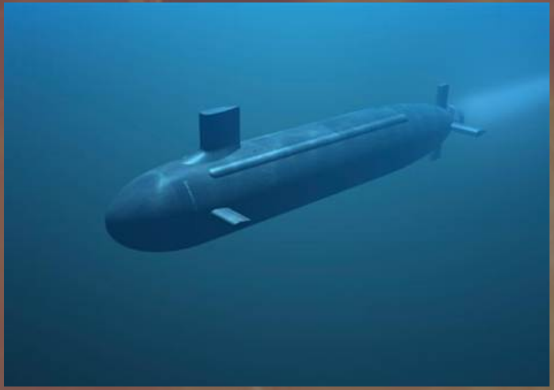
Laser Use

- **Commercial**
  - Supermarket checkout scanners
  - Determining site boundaries for construction
  - Communications
- **Industrial**
  - Cutting
  - Welding



Laser Use

- **Military**
  - Shhh….It's a secret!



Characteristics of Lasers and the Associated Laser Hazard

<u>Spectral characteristic – Wavelength</u>

In general, shorter wavelengths are more hazardous in any spectral region, but Near Infrared lasers are the most hazardous because they are invisible retinal hazards.

<u>Temporal characteristic – Pulse Duration</u>

In general, pulsed lasers are more hazardous than CW lasers.
The shorter the pulse duration, the higher the peak power and the greater the hazard.

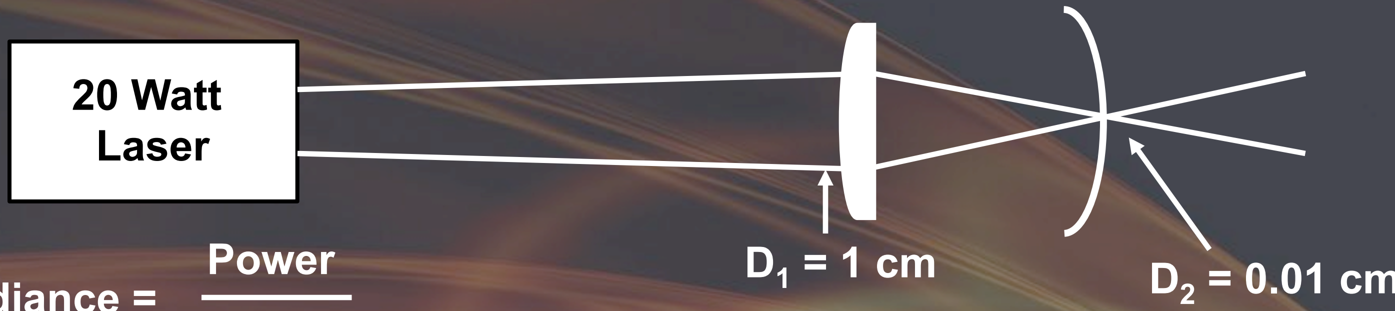
<u>Spatial characteristic – Beam Divergence</u>

Low beam divergence results in a large intrabeam hazard distance.

<u>Focusing characteristic</u>

High retinal irradiance of focused beam creates extreme retinal hazard for visible and near infrared lasers.

Irradiance: An Important Measure



$$\text{Irradiance} = \frac{\text{Power}}{\text{Area}}$$

$$\text{Area} = \frac{\pi D^2}{4}$$

IRRADIANCE AT LENS:

$$E_1 = \frac{20 \text{ watts}}{(3.14)(1\text{cm})^2/4}$$

$$E_1 = 25 \text{ watts/cm}^2$$

IRRADIANCE OF FOCUSED SPOT:

$$E_2 = 250{,}000 \text{ watts/cm}^2$$

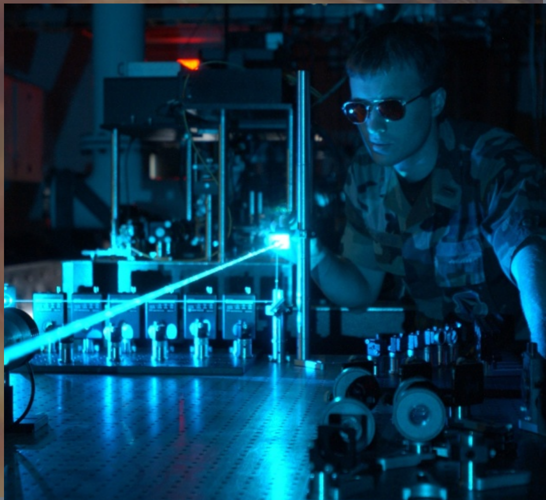
Irradiance is an important measure of the strength of the laser at a location.

The focusing characteristics of laser light is one of the main eye hazard. When visible light enters your eyes it is focused to the back of the eye in the retina region and it can reduce the area in which the beam interacts. For example, reducing the diameter by a factor of *100* the irradiance is increased by a factor of *10,000*.

LASER BEAM INJURIES

Open laser beams can cause severe eye injuries resulting in permanent vision loss to the unprotected eye.

High powered lasers can cause also cause skin burns if protective equipment is not worn.



Laser Skin Injuries

THERMAL SKIN INJURIES

Surface burns from high power beams similar to an open flame

Deeper burn penetration at 1 μm wavelength

Tissue vaporization by focused beams

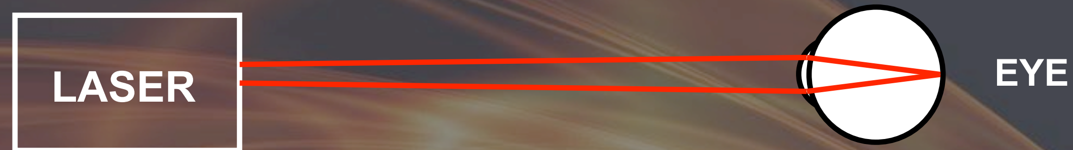
PHOTOCHEMICAL SKIN INJURIES

Sunburn from scattered UV exposure

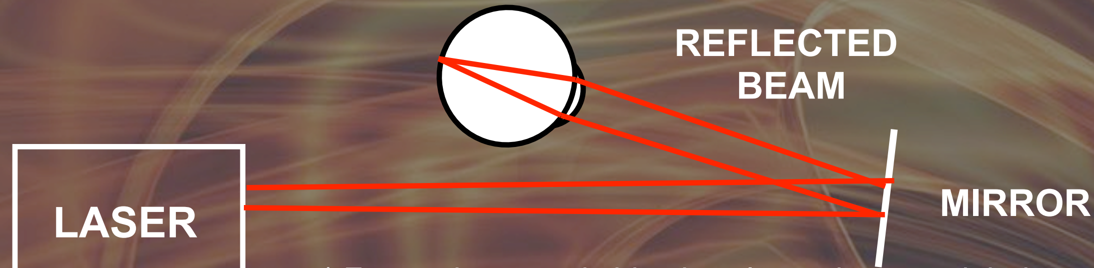
Possibility of skin cancer from long term UV exposure

Types of Laser Eye Exposures

Intrabeam Viewing

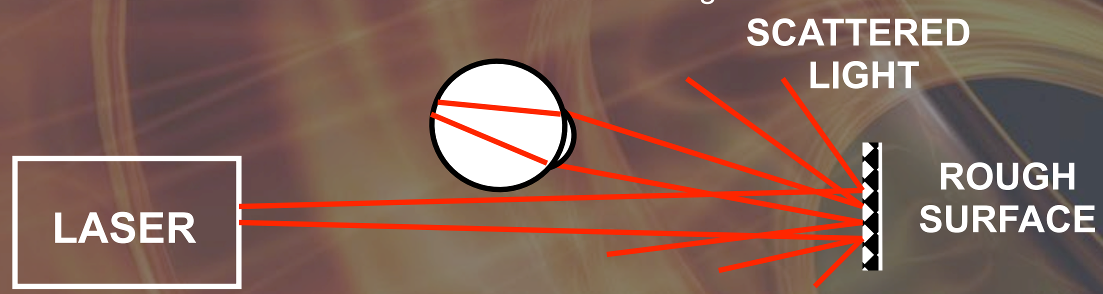


Specular Reflection



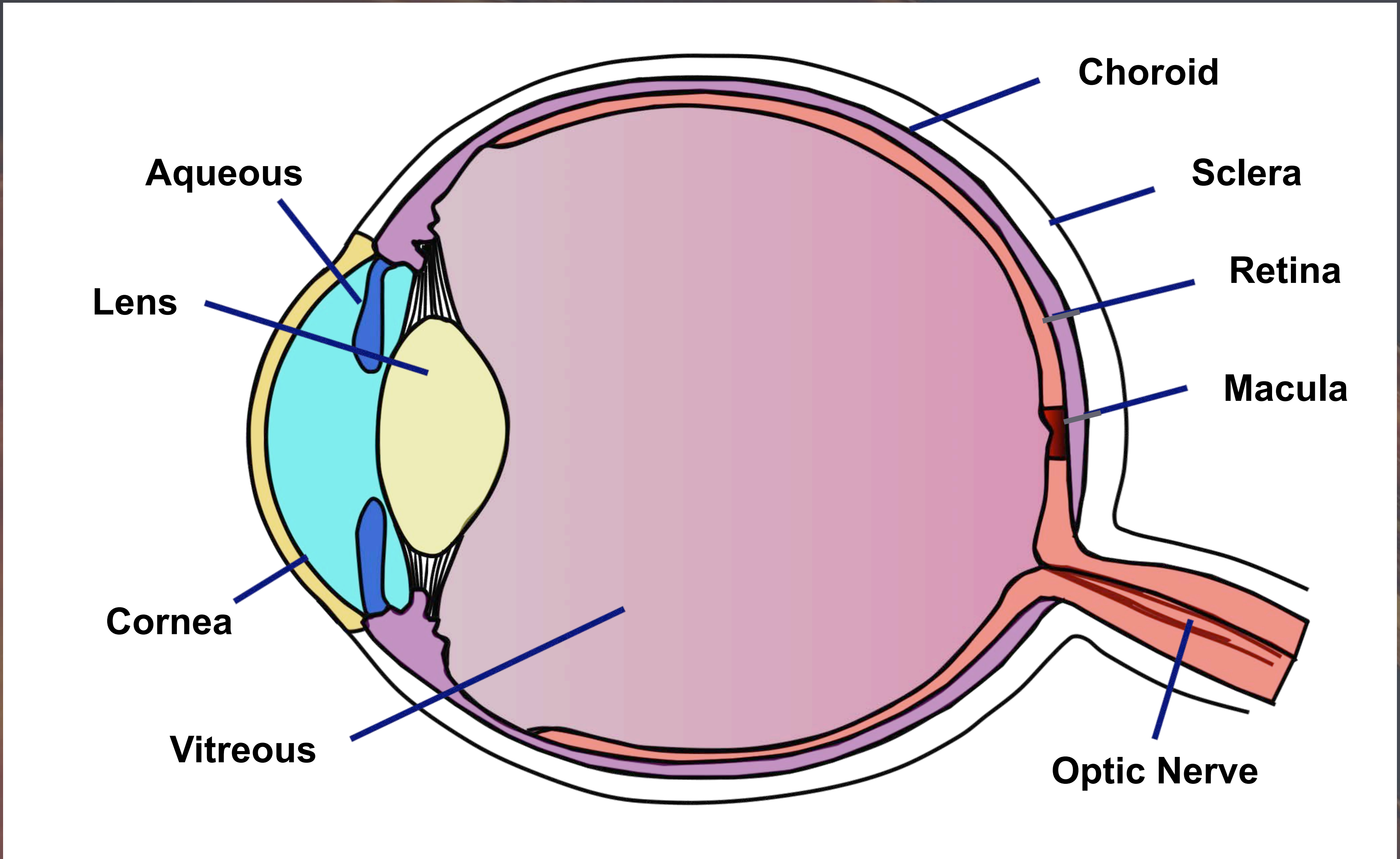
* From mirrors and shiny jewelry and causes injuries similar to intrabeam viewing.

Diffuse Reflection

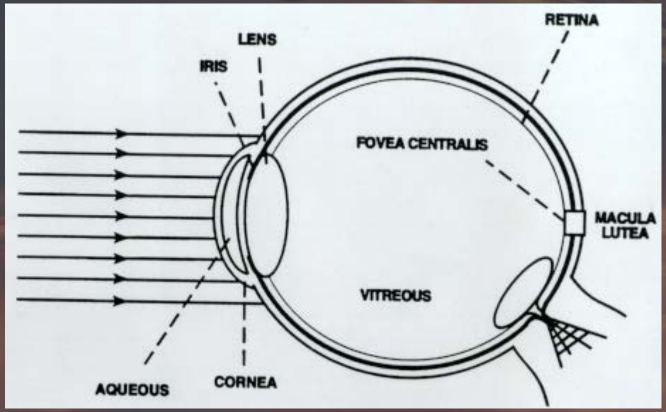


* A hazard for high powered lasers

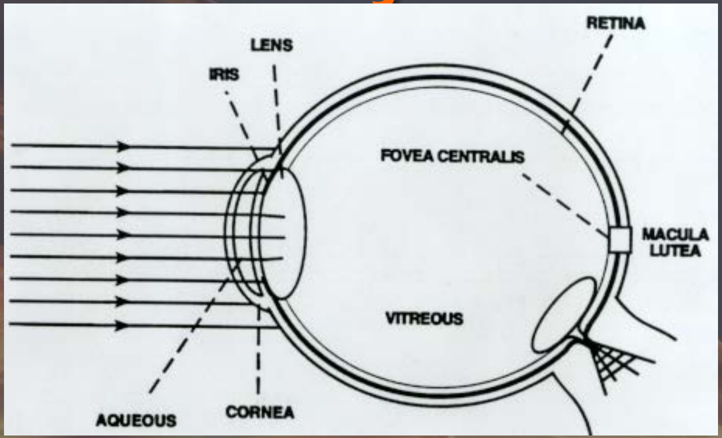
Structure of the Human Eye



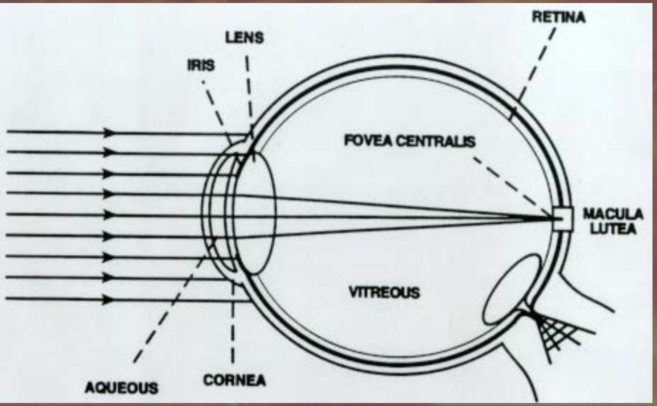
Biological Effects to the Eyes



Near-ultraviolet (100-330 nm)
Possible damage to Cornea

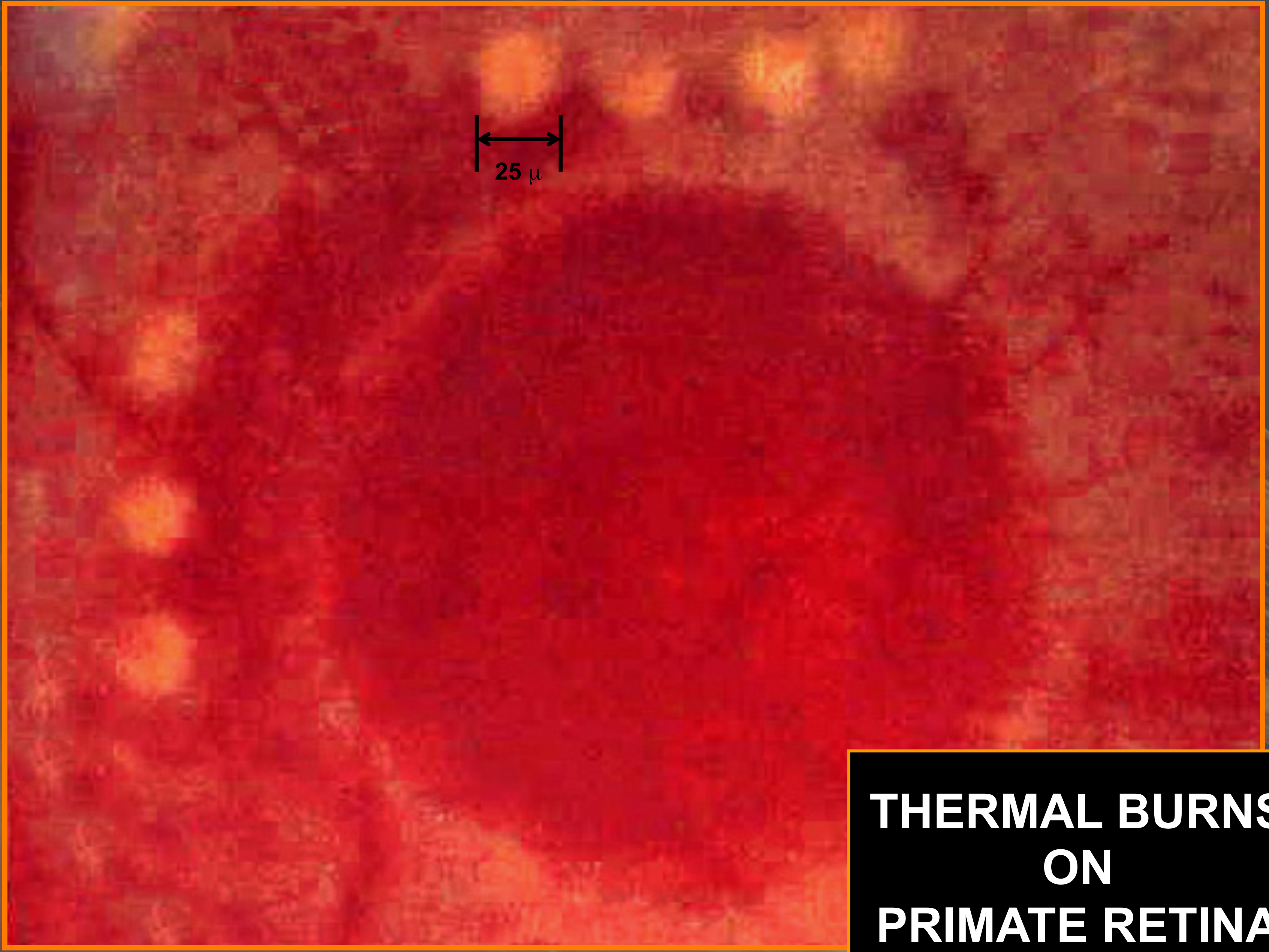


Far-IR (1400-10600 nm)
Possible damage to Lens



Damage to the macula lutea region could result in loss of fine vision abilities like reading and threading a needle

Visible and Near IR (400-700 nm/700-1400 nm)
Possible damage to Retina

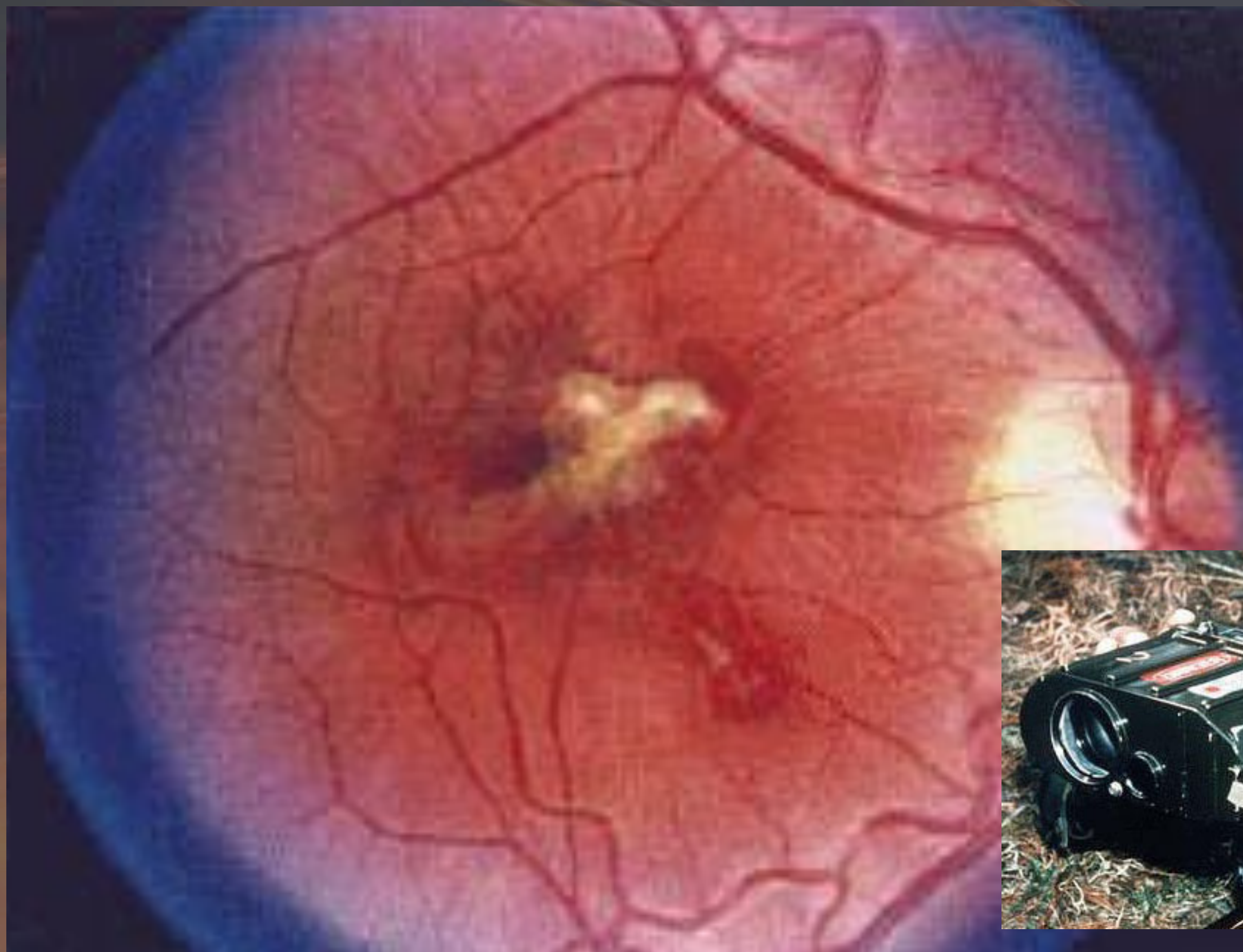


THERMAL BURNS
ON
PRIMATE RETINA

MULTIPLE PULSE RETINAL INJURY

EYE INJURY BY Q-SWITCHED LASER

Retinal Injury produced by four pulses from a Nd:YAG laser range finder.



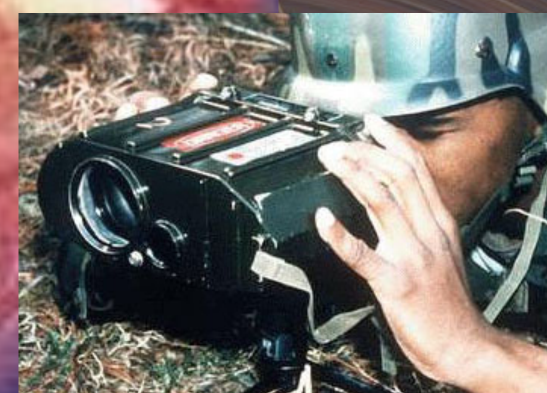


Photo courtesy of U S Army Center for Health Promotion and Preventive Medicine

Common Causes of Laser Accidents

Studies of laser accidents have shown that there are usually several contributing factors. The following are common causes of laser injuries:

- Inadequate training of laser personnel (leading cause)
- Alignment performed without adequate procedures
- Failure to block beams or stray reflections
- Failure to wear eye protection in hazardous situations
- Failure to follow approved standard operating procedures or safe work practices

Non-Beam Hazards

- Electrical hazards (shock) from high voltage power supply & capacitors
- Smoke & fumes
- Mechanical hazards
- Process radiation (UV)
- Flashlamp light (Welder's flash)
- Chemical hazards

In many cases the hazards from exposure to laser light are controlled so well that the greatest risk to workers is from a non-beam hazards associated with laser use. The most serious hazard associated with lasers is the electrical hazard from the laser power source. Several fatalities have occurred because of this hazard.

LASER HAZARD CLASSES

Lasers are classified from 1 to 4 according to the level of laser radiation that is accessible during normal operation. Where 1 is the least dangerous and 4 represents the highest amount of risk.

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 2

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

* Aversion responses are the involuntary reaction you have to the effects like bright lights. This is approximately a quarter of a second response time.

Laser Scanners

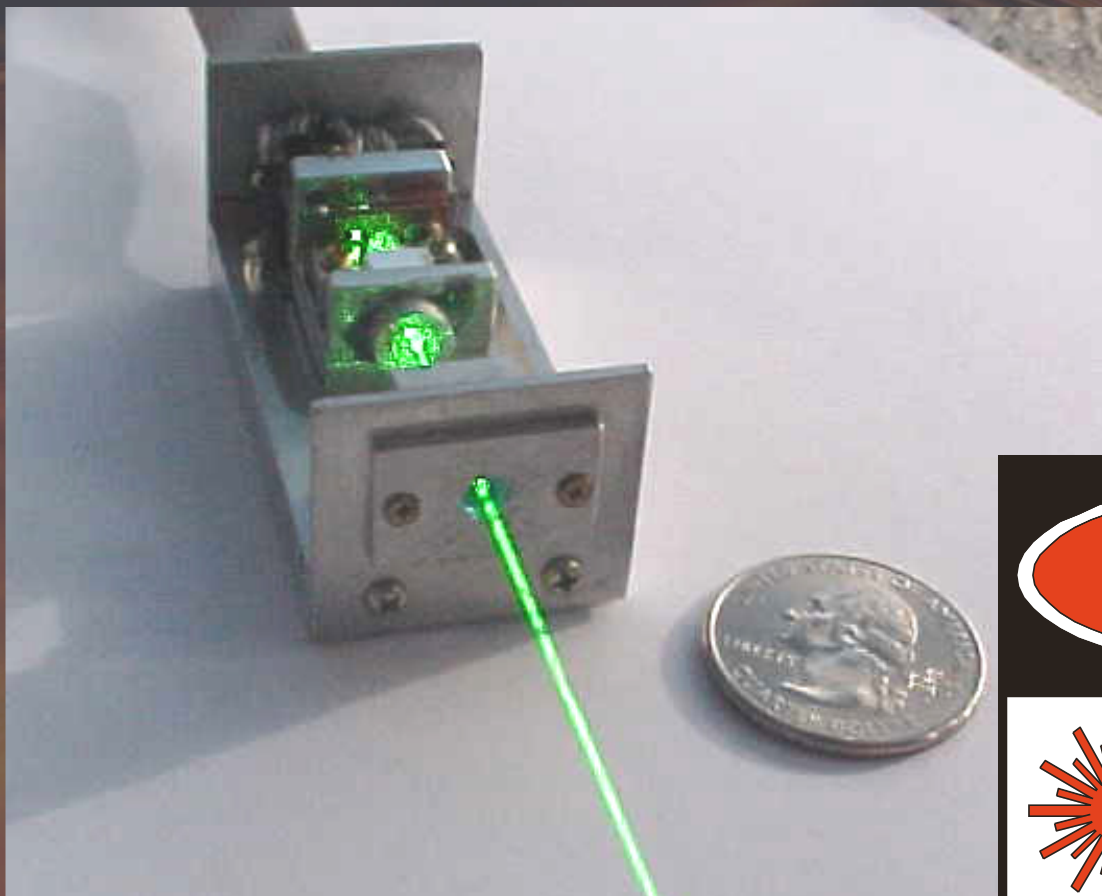
CLASS 3R (Formerly 3a)

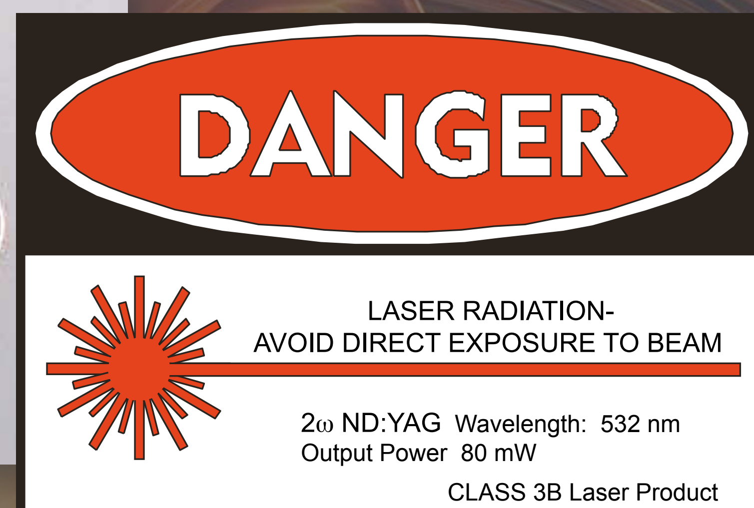
- **Aversion response may not provide adequate eye protection**
- **CW maximum power (visible) 5 mW**

CLASS 3B

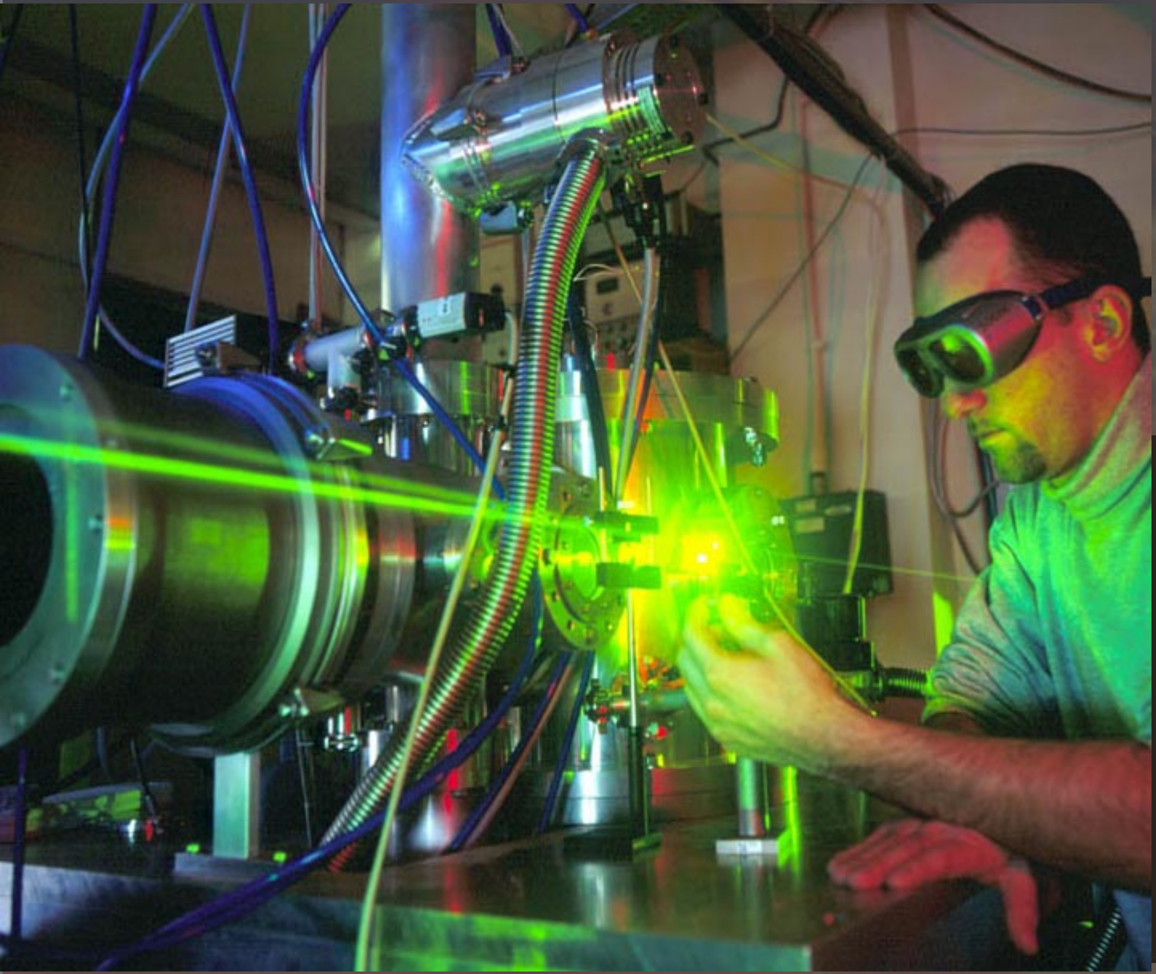
- Direct exposure to beam is an eye hazard
- Visible or invisible
- CW maximum power 500 mW

DPSS Laser with cover removed

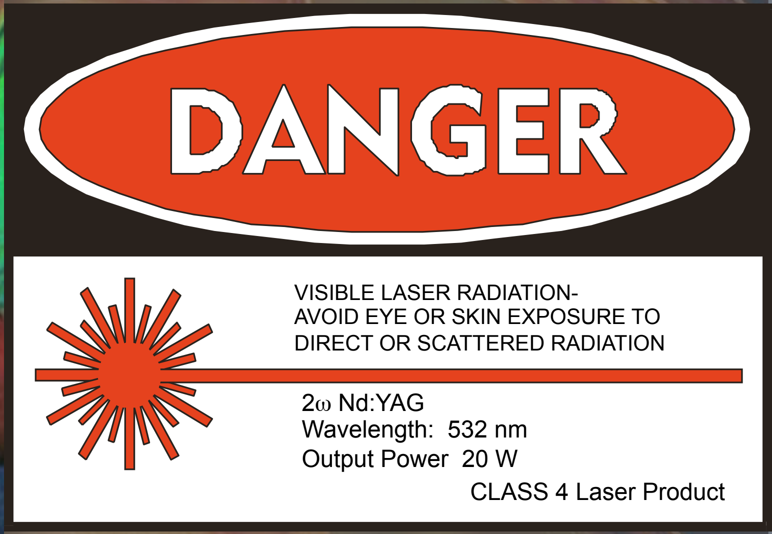




CLASS 4



- Eye and skin hazard when exposed to direct or scattered beam
- Visible or invisible
- CW power >500 mW
- Can be a fire hazard



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

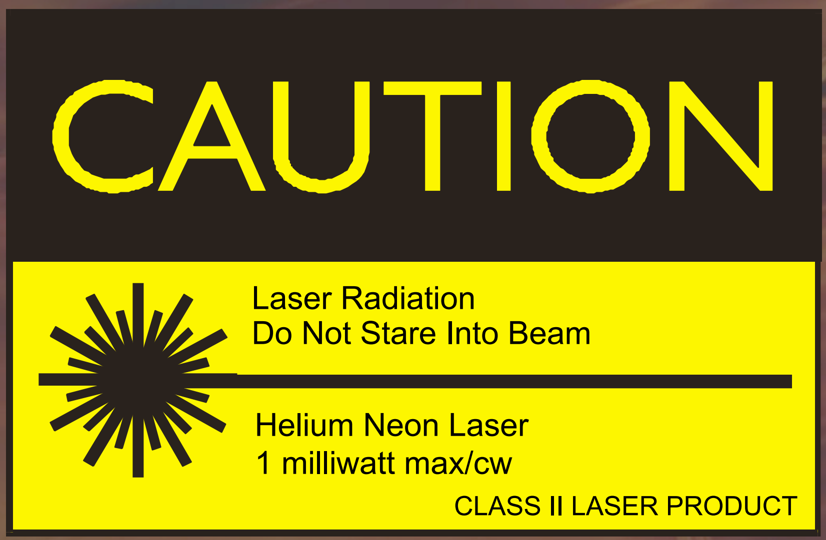
LASER SAFETY STANDARDS

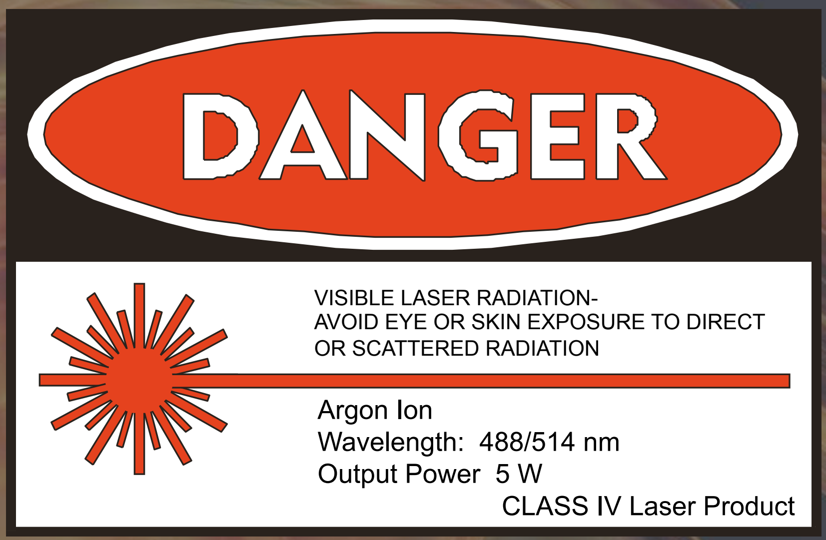
- The Federal Laser Product Performance Standard (FLPPS) of the Center for Devices and Radiological Health (CDRH)
  This is federal law and applies to the manufacture of lasers.

- The American National Standard for Safe Use of Lasers (ANSI Z136.1)
  This is a VOLUNTARY Standard that applies to the use of lasers.
  It is “recognized by” :
  The Occupational Safety and Health Administration (OSHA)

- State of Texas Radiation Control: Radiation Safety Requirements for Lasers 25 TAC §289.301 http://www.dshs.state.tx.us/radiation/rules.shtm

CDRH Class Warning Labels



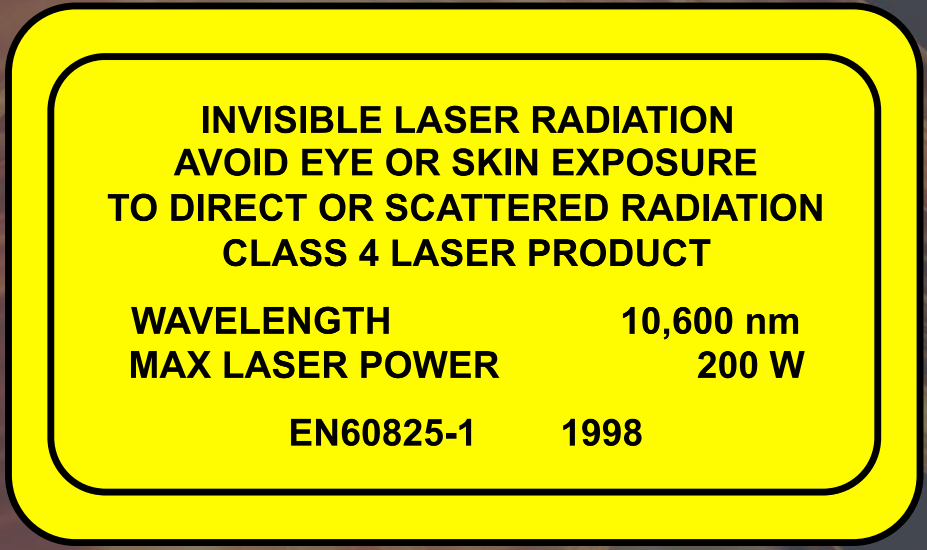


Class 2
Class 3R (IIIa) with expanded beam

Class 3R (IIIa) with small beam
Class 3B
Class 4

International Laser Warning Labels

Symbol and Border: Black
Background: Yellow



Legend and Border: Black
Background: Yellow

Laser Exposure Limits

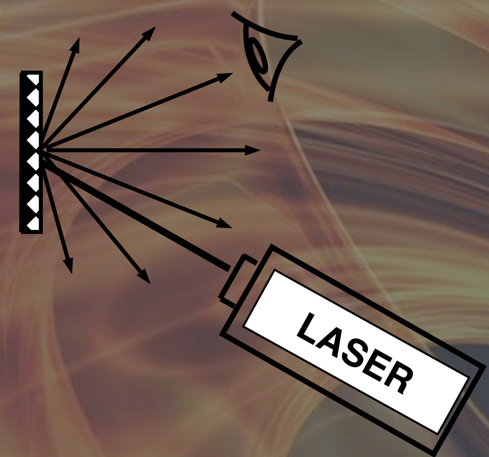
Maximum Permissible Exposure (MPE) is defined as the level of laser radiation to which a person may be exposed without hazardous effect or adverse biological changes in the eye or skin. The MPE of a specific laser is determined based on the wavelength and exposure duration.

Nominal Hazard Zone (NHZ) is the space within which level of the direct, reflected, or scattered radiation during normal operation exceeds the applicable MPE. Exposure levels beyond the boundary of the NHZ are below the appropriate MPE level.

Nominal Hazard Zone

Within the Nominal Hazard Zone, appropriate eye & skin protection should be worn.

Intrabeam
Nominal Hazard Zone



Diffuse Reflection
Nominal Hazard Zone

Hazard Evaluation by Laser Users

All users of lasers with exposed beams should:

- Understand the hazards associated with the laser they use
- Evaluate the control of hazards every time they operate the lasers
- Use their best judgment in controlling all laser hazards (be conservative; don't take chances)
- Consult with Radiation Safety whenever they have safety concerns or questions (713-500-5840)

LASER CONTROL MEASURES

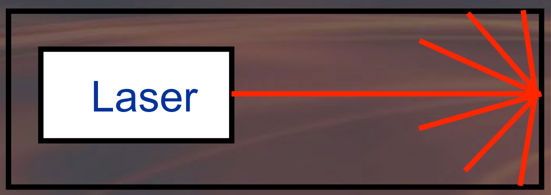
"Control Measures shall be devised to reduce the possibility of exposure of the eye and skin to hazardous levels of laser radiation."

Types of Control Measures

- **Engineering**
- **Administrative**
- **Procedural**

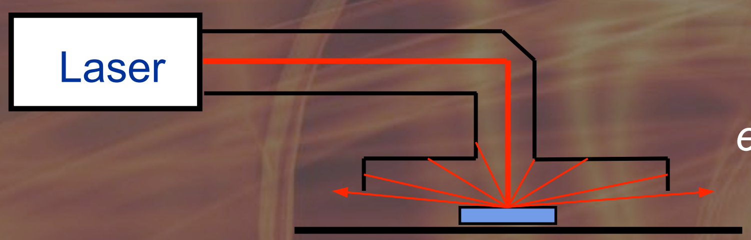
Beam Path Enclosures

FULLY ENCLOSED BEAM PATH



Class 1 System

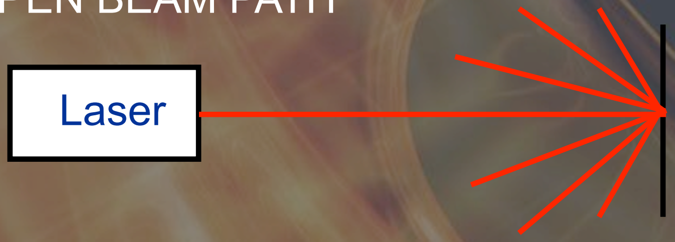
LIMITED OPEN BEAM PATH



Some scattered light escapes. NHZ is small.

FULLY OPEN BEAM PATH

Larger NHZ requires laser controlled area.



Even partial beam exposures can be dangerous

SKIN BURN FROM CO_2 LASER EXPOSURE

Accidental exposure to partial reflection of 2000 W CO_2 laser beam from metal surface during cutting

Open Beam Control Measures

- Laser Controlled Area (usually the lab area)
- Appropriate Eye Protection
- Beam Control (Beam Blocks)
- Administrative and Procedural Controls
- Education and Training

DANGER

Must include potential hazards → VISIBLE and/ or INVISIBLE LASER RADIATION-AVOID EYE OR SKIN EXPOSURE TO DIRECT OR SCATTERED RADIATION.

ND:YAG 1064 nm ← Include type of laser and wavelength

100 Watts Max. Average Power

Include max power output and Class of laser → CLASS 4 LASER

Controlled Area Warning Sign

Entryway Controls for Class 4 Lasers

1. *Non-Defeatable Entryway Controls*
   - Doorway interlock is non-defeatable
   - Training of authorized users only

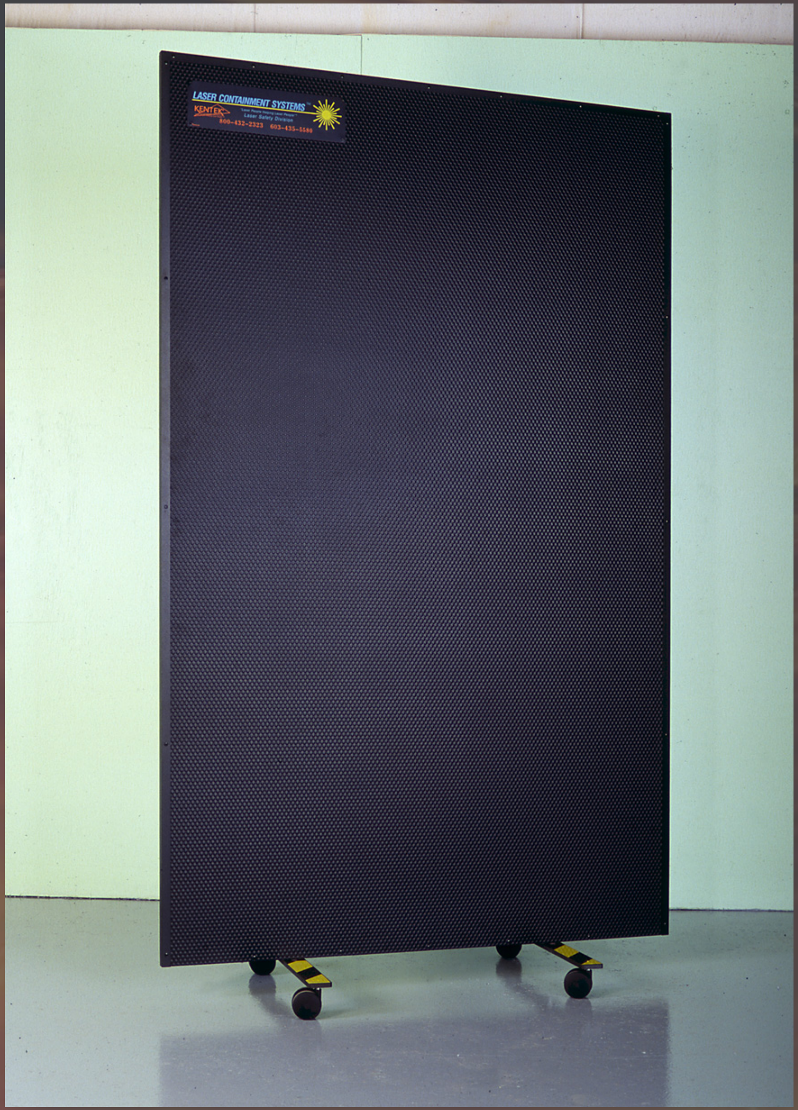
2. *Defeatable Entryway Controls*
   - Doorway interlock is defeatable
   - Training of all personnel with access
   - Barrier and eyewear at door

3. *Procedural Entryway Controls (Method commonly used at UTHSC-H)*
   - No doorway interlock
   - Training of all personnel with access
   - Barrier and eyewear at door
   - Visible or audible signal at doorway

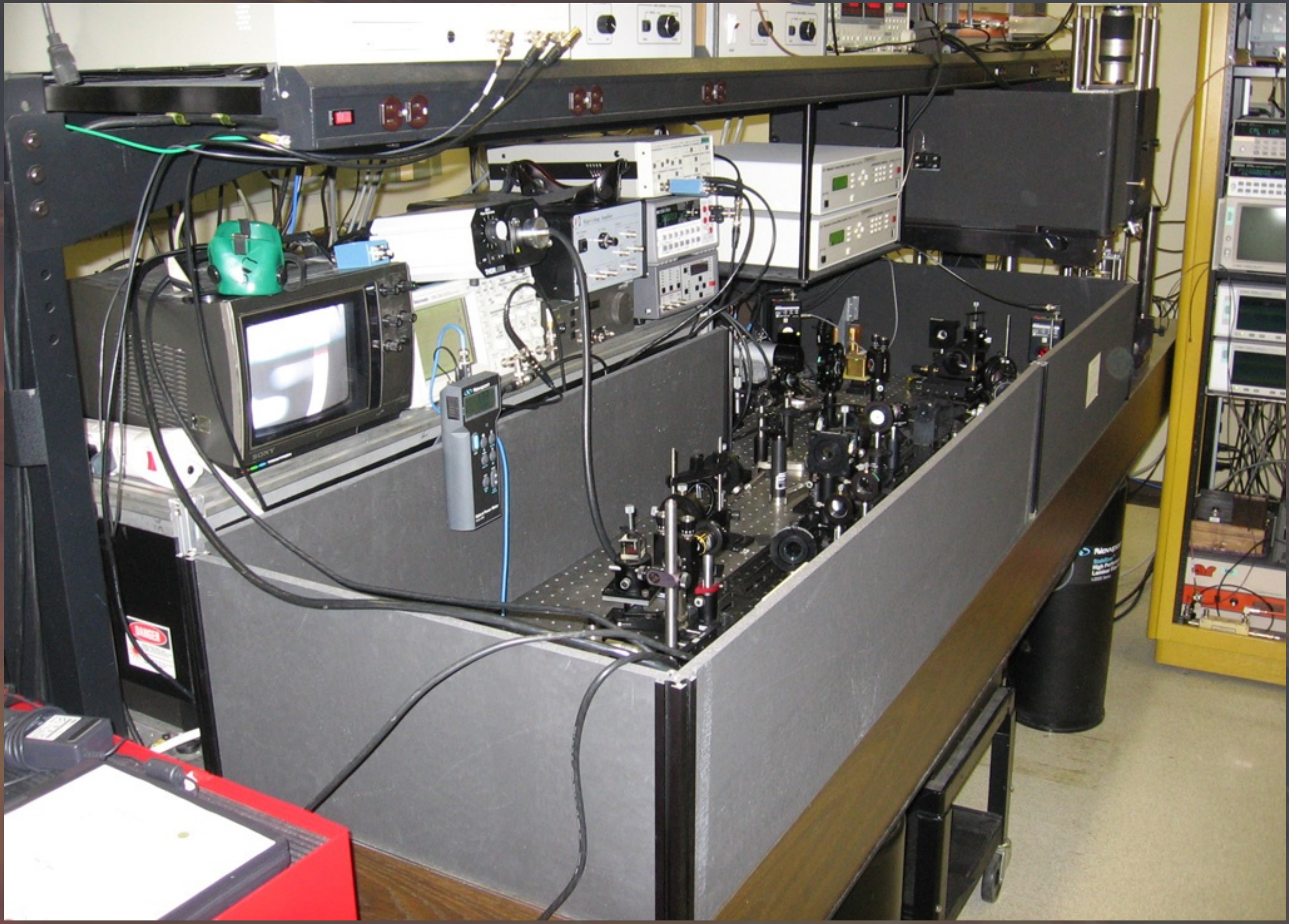
Laboratory Door Interlock

Entryway Warning Lights

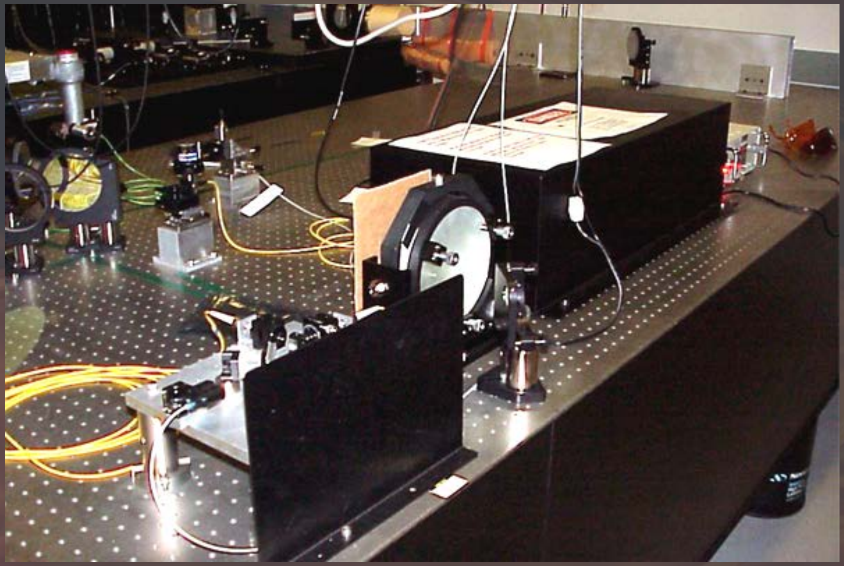
Laser Protective Barriers

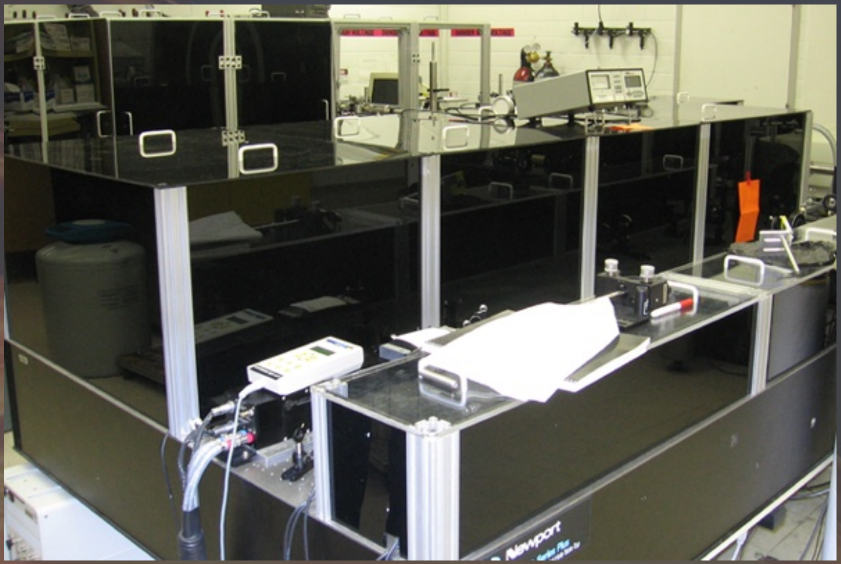


Curbs on Optical Table

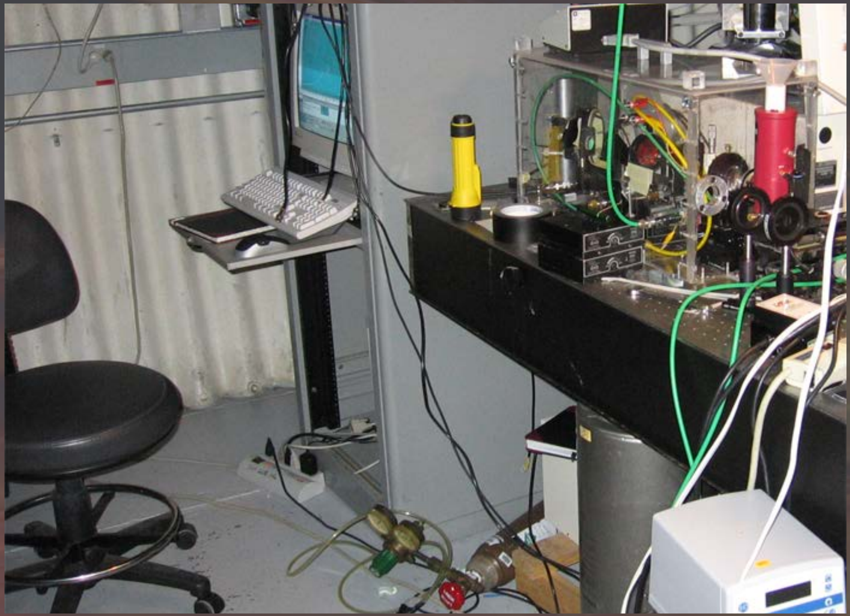


Control of Laser Beam





Computers in Research Labs



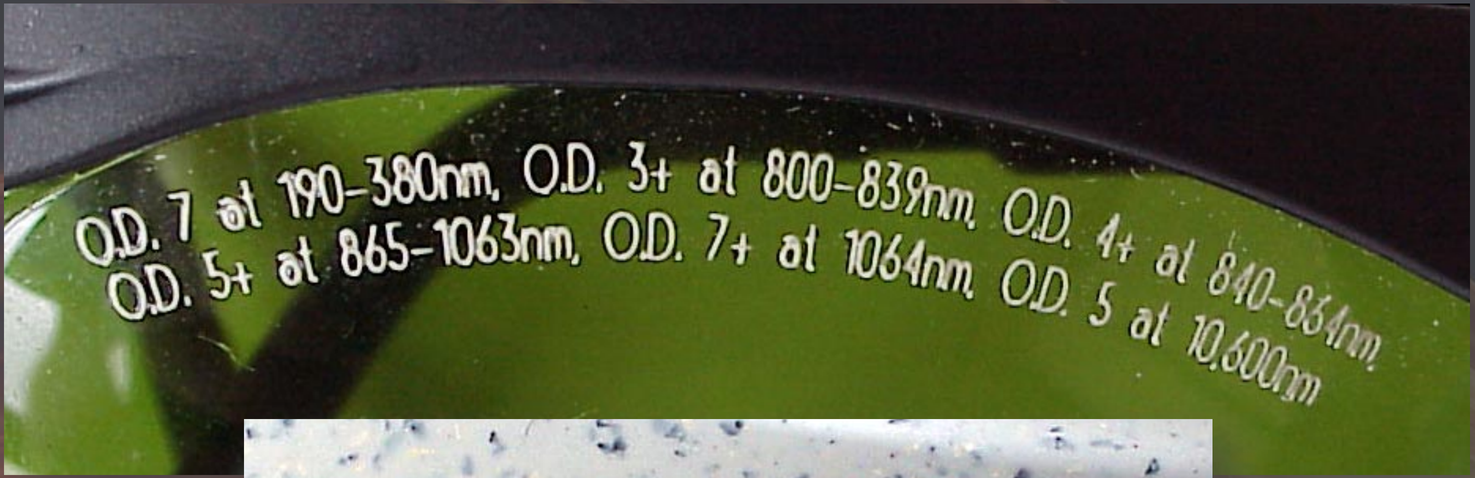
Allowing a direct view from a computer workstation into a laser experimental setup increases the risk of eye exposure to reflected beams.

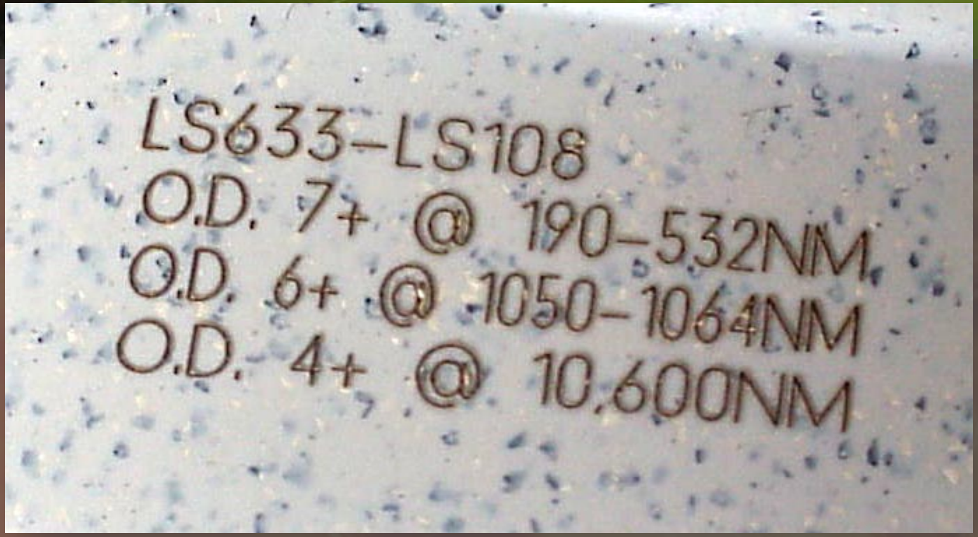
<u>All computer monitors must be at a higher level then the laser.</u>

Laser Safety Eyewear Selection

Your eyewear when working with lasers must be in the appropriate wavelength and optical density. No one eyewear fits all lasers.

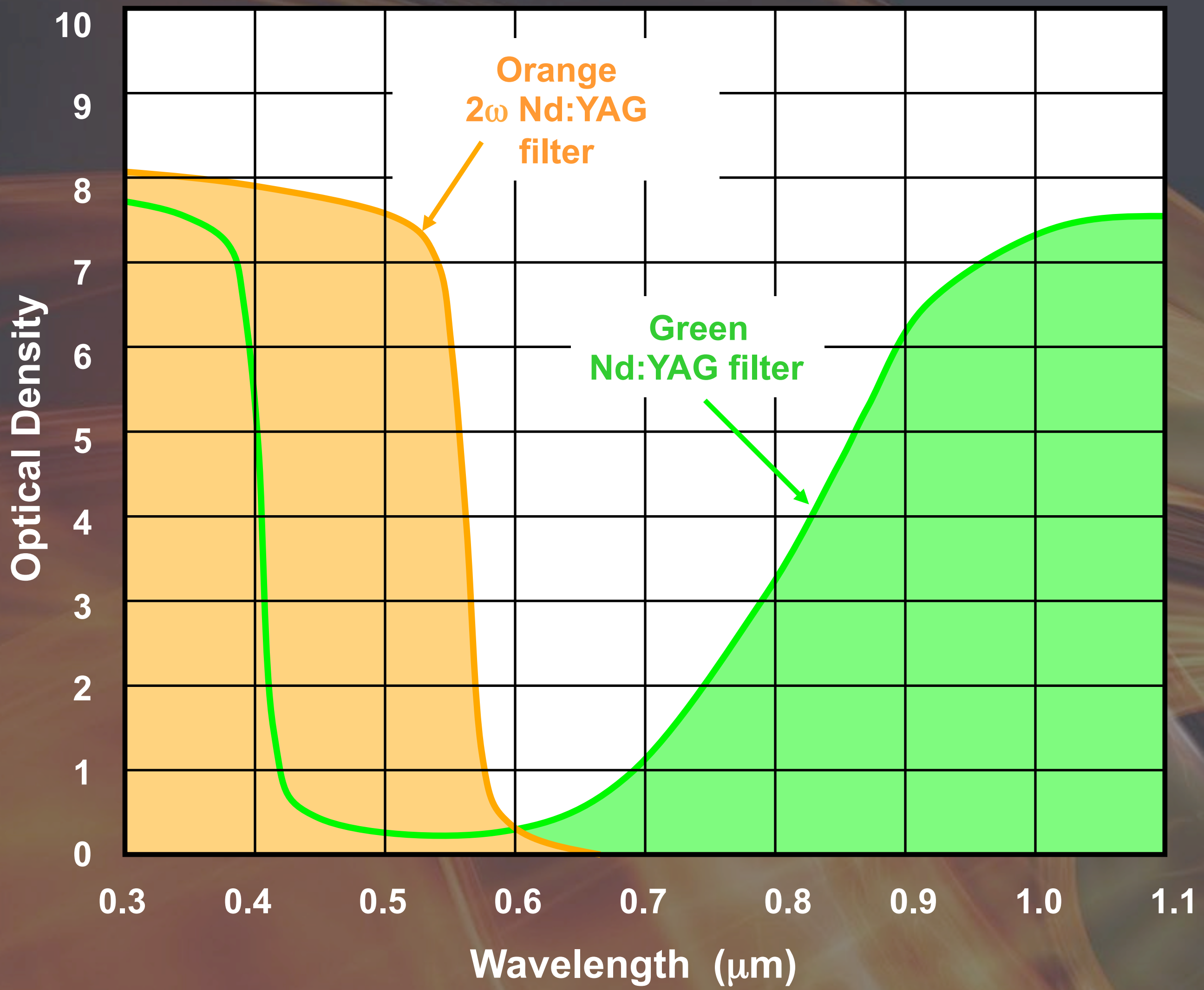
Laser Eyewear Labels





All eyewear must be labeled with wavelength and optical density.

PLASTIC EYEWEAR CHARACTERISTICS



Safe Work Practices with Lasers

- Never intentionally look directly into a lase Do not stare at the light from any laser. Allow yourself to blink if the light is too bright.
- Do not view a Class 3R (3a) or any higher power laser with optical instruments.
- Never direct the beam toward other people.
- Operate lasers only in the area designed for their use and be certain that the beam is terminated at the end of its use path. Never allow a laser beam to escape its designated area of use.
- Position the laser so that it is well above or below eye level.

Safe Work Practices with Lasers

- Always block the beam with a diffuse reflecting beam block.
- Remove all unnecessary reflective objects from the area near the beam's path. This may include items of jewelry and tools.
- Do not enter a designated Class 3B or Class 4 laser area (posted with a DANGER sign) without approval from a qualified laser operator. Eye protection is required in these areas.
- Always wear laser safety eyewear if a class 4 invisible beam is exposed.

Emergency Procedures

In the event of an emergency such as fire or injury:

- **Shut down** the laser system
- Provide for the safety of the personnel, i.e. first aid, CPR, etc.
- If necessary, contact the UT Police at 500-HELP or 713-500-4357 or the fire department
- Inform the Radiation Safety Program at 713-500-5840
- Inform the Principal Investigator

DO NOT RESUME USE OF THE LASER SYSTEM

WITHOUT APPROVAL OF THE RADIATION SAFETY PROGRAM.

Questions????