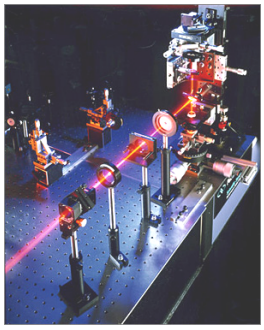
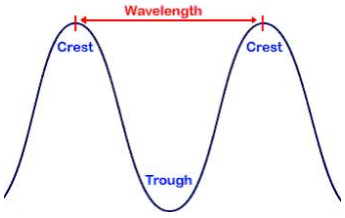


Laser Safety Awareness Training Handout

San Francisco State University
1600 Holloway Avenue
San Francisco, California 94132
Laser Safety Officer: Linda Vadura, lvadura@sfsu.edu

I. Laser Fundamentals – show video

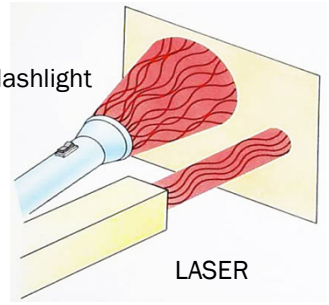


Wavelengths (λ) are usually measured in **nanometers (nm)**

A. Definitions

1. **Energy measured in Joules (J)**
2. **Power given in Watts (W)**
   1 Watt = 1 Joule per second
3. **Irradiance** – amount of Power per unit area
4. **Wavelength** – the distance between crests of a wave.
5. **Optical Density (OD)** – Relates to absorbance of light by a lens or viewing glass and is used in the determination of the appropriate eye protection.

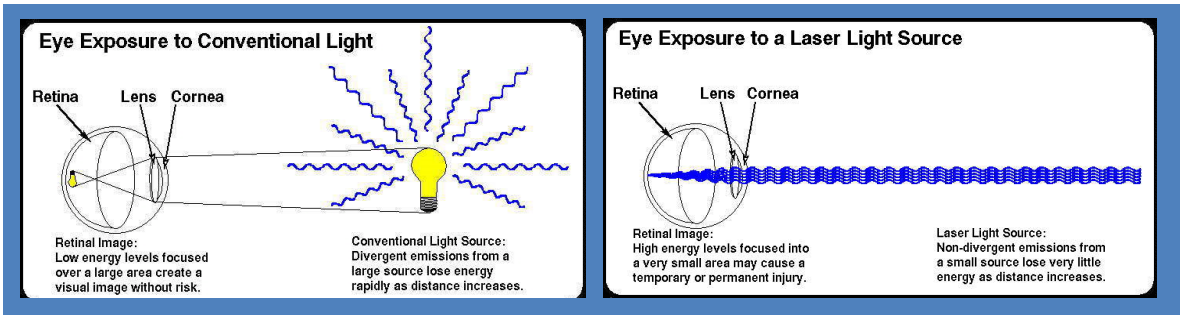
B. Properties of Natural Light



1. Polychromatic
2. Non-directional
3. Incoherent
4. High divergence

C. Properties of Laser Light

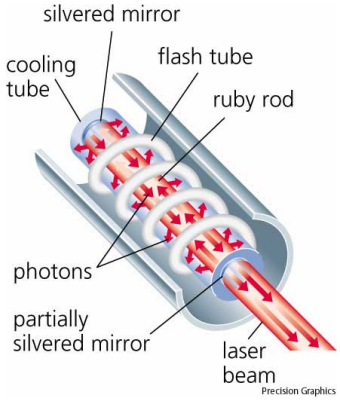
1. Monochromatic
2. Directional
3. Coherent
4. Low Divergence
5. **High-Irradiance:** Concentrated power in small area (power density: irradiance)



D. Simple Laser

1. **Parts**
   a) **Lasing Medium** – solid, liquid, gas, or semi-conductor
   b) **Excitation Mechanism** – flashlamps, electricity, chemicals, other lasers
   c) **Optical Resonator** – 2 mirrors in parallel perpendicular to the optical axis to laser where light can circulate (between the two mirrors) to amplify the light.

2. **Output**
   a) **Continuous Wave**
   b) **Pulsed**



E. Types of Lasers

1. **Solid State lasers**
2. **Semiconductor lasers**
3. **Liquid lasers**
4. **Gas lasers**

F. Classifications

1. **Class 1 –** Safe under normal operation

2. **Class 1M –** Considered incapable of producing hazardous exposure unless viewed with collecting optics. Safe **unless optical instruments* used.**

3. **Class 2 –** Visible wavelengths. Power < 1 mW, visible wavelengths. Relies on human aversion response to prevent injury based on maximum exposure time of 1000 seconds. Safe for accidental exposure (<0.25 s).

4. **Class 2M –** *(Expanded beam Class 3A)* Same as Class 2 but with a highly diverging beam. Safe for accidental exposure (<0.25) **unless optical instruments used***

5. **Class 3R –** *(formerly Class 3A)* Power: 1mW to 5mW
   Potentially hazardous under some direct and specular reflection viewing conditions. Low risk compared to Class 3B.

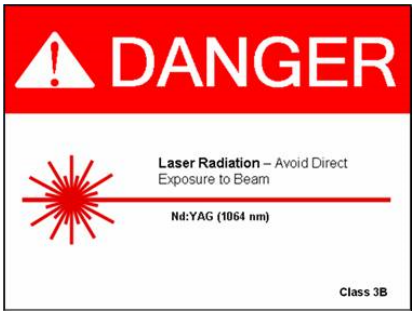
6. **Class 3B –** Power: 5mW to 500mW continuous / < 125mJ pulsed
   Present potential eye hazard for intrabeam or specular conditions.

7. **Class 4 –** Power: Any output above Class 3B.
   Present potential acute hazard to the eye and skin for both direct and *diffused* conditions. Also have potential hazard for fire and byproduct emissions from target or process materials.

**Optical instruments - Binoculars, telescopes, microscopes, magnifying glasses (but not prescription glasses)*

***Diffused reflection - Reflection of radiation from a matte surface such as a wall*

II. Laser Certification & Labeling



A. Label Information

1. **Hazard class**
2. **Safety features**
3. **Federal compliance**

   CDRH - Center for Devices and Radiological Health
   (part of the FDA—Food and Drug Administration)

B. Class warning label

1. **Required on all except class 1**
2. **Signal word**
   a) Caution – Class 2, 2M, and class 3R, power below MPE
   b) Danger – Class 3R, class 3B and class 4, power above MPE
3. **Also contains warning phrase, signal burst symbol, laser type, classification, and output characteristics.**

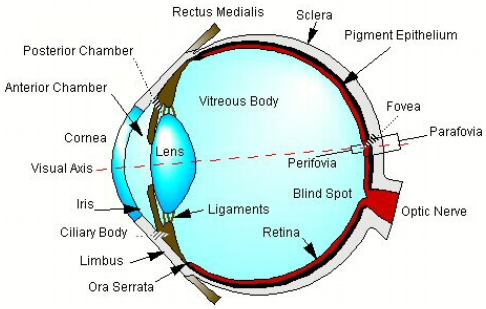
C. Aperture Label – indicates where beam exits system

D. Protective Housing Label – on any removable portion of enclosure

III. Laser Hazards

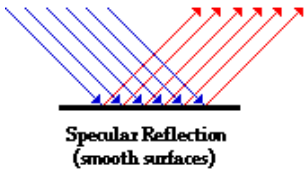
A. Eye Hazards

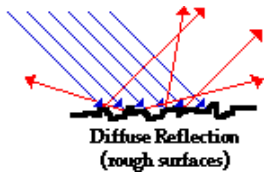
1. **The eye's lens focuses incoming light onto the retina at a magnification of** (or increases the irradiance by a factor of) **100,000 to 150,000.**
2. **Lens damage:** can lead to cataracts
3. **Retinal damage:** fovea damage can result in loss of reading or working vision
4. **Extent of damage determined by:**
   - Part of eye exposed
   - Beam Irradiance (or Power Density)
   - Length of exposure
   - Wavelength
     - **lens, cornea** *: (UVA)* 320-400 nm
     - **retina (esp. fovea):** *(Visible & IR-A)* 400-1400 nm
     - **cornea** *: (UVC & UVB)* 100-320 nm and *(IR-B & IR-C)* 1,400-1,000,000 nm



B. *Skin Hazards*

1. **Epidermis:** reddening of the skin, photochemical damage
2. **Dermis:** thermal effects, such as burns (≥ 1W)
3. **Subcutaneous Tissue:** loss of hair
4. **Extent of damage determined by:**
   - Length of exposure
   - Part of eye exposed
   - Beam irradiance (or Power density)
   - Wavelength:





C. *Types of Exposure*

1. **Intrabeam** – directly viewing beam (e.g. during alignment)
2. **Specular** – direct reflection (e.g. mirror, no scatter)
3. **Diffuse** – reflection from a rough surface (problem with Class 4s)

D. *M.P.E. – Maximum Permissible Exposure*

The level of laser radiation to which a person may be exposed without hazardous effect or adverse biological changes in the eye or skin. MPE is expressed in terms of either radiant exposure (joules/cm^2) or irradiance (watts/cm^2).

E. *Aversion Response – body's protective response to light, "blinking"*

1. **Response is triggered only by visible light. (0.25 sec response time)**
2. **Example: Exposure to high power Nd:YAG laser emitting invisible 1064 nm radiation, may not feel pain or notice immediate damage to their eyesight.** *(thus, no aversion response i.e., no blink)*
3. **A pop or click noise emanating from the eyeball may be the only indication that retinal damage has occurred.**

F. *Optical Density – logarithmic function corresponding to the amount of light that a lens transmits at a specific wavelength, i.e., the attenuation factor at a given wavelength.*

1. **Transmittance, or the amount of light that passes through a lens, is a decimal fraction of the total light you started with.** So if a lens transmits 0.01% of the light at a specified wavelength, its decimal fraction transmittance, or T, would be 0.00001. OD=log(1/T)
2. **Method:** Work out the maximum accessible emission from the laser and divide it by the MPE for the laser radiation. The log of this number is the minimum required OD for the eyewear.
3. **Example:** Eyewear which attenuates Nd:YAG laser radiation by a factor of 1,000,000 has an OD of 6 at 1064 nm.

Example

What level optical density laser safety glasses should I wear when I use my 150mW laser. It is a green 532nm laser with a divergence of 1.2mRad.

Your laser safety glasses should have an optical density or OD of between 3 and 4. If the optical density is more than four, visibility will be too low and you'll have trouble pointing or aiming your laser. If optical density is lower, the laser safety glasses will not provide enough protection at higher power levels.

G. *Non-Beam Hazards*

1. **Chemical Hazards** – Some materials used in lasers *(i.e. excimer, dye, and chemical lasers)* may be hazardous and/or contain toxic substances. In addition, laser induced reactions can release hazardous particulate and gaseous products.

2. **Electrical Hazards** – Lethal electrical hazards may be present in most lasers, particularly in high power laser systems.

3. **Other Secondary Hazards**
   a) Cryogenic coolants
   b) X radiation from faulty high-voltage (>15kV) power supplies
   c) Explosions from faulty capacitors and flash lamps
   d) Fire Hazards
   e) Confined space and housekeeping hazards
   f) Compressed gases

IV. Laser Safety Tools

Beam Dump

A. *Engineering Controls/Measures*
(automatic, preventive)

1. **Interlocks**
2. **Curtains, enclosures, beam blocks, beam dumps**
3. **IR viewers, sensor cards, remote viewing**
4. **Walking path barriers**

Infrared Viewers

B. *Administrative Controls/Measures*
(requires people to act)

1. **Labels**
2. **Signs**
3. **Procedures**
4. **Security/Access Restrictions**

Infrared and Ultraviolet Sensor Cards

C. *Personal Protective Equipment*
(YOU are the limiting factor)

1. **Knowing when to use which type of protection**
2. **Shielding skin with protective clothing**
3. **Laser Eyewear** – Filter lowers beam intensity to MPE
   - Wavelength
   - Optical Density (OD)
   - Field of vision
   - Fit
   - Visible Light Transmission

Laser Eyewear

D. Laser Eyewear

1. The two most important considerations
   a. Wavelength
   b. Optical Density

2. Light Transmission
   a. Generally we mean the percentage of visible light that penetrates a lens.
   b. For a normal pair of safety spectacles or prescription glasses the Visible Light Transmission (VLT) is about 85%.

3. Optical Density
   The OD of eyewear is the log of the attenuation factor at a given wavelength. Thus eyewear which attenuates Nd:YAG laser radiation by a factor of 1,000,000 has an OD of 6 at 1064 nm.

4. Alignment Eyewear
   From the point of view of safety it is better if we can tell where the beam is, since we are then less likely to expose ourselves to it. Also sometimes it is necessary to be able to see where the beam is for purposes of alignment.
   - Balances the Optical Density between protection and visibility of the beam
   - Protects against the beam in the case of accidental direct exposure to the eye
   - Allows the wearer to see the spot from the beam
   - Reduces the power of the laser beam to below the Class 2 limit *(ie 1 mW for CW lasers)*
   - Is not designed for intentional direct viewing of the beam

LSO—Laser Safety Officer
Linda Vadura
Email: lvadura@sfsu.edu
Office: 415.338.6892
Website: https://ehs.sfsu.edu/

V. Laser Program at SFSU

A. Training

1. Initial laser safety orientation/awareness
2. On-the-Job operations training with P.I./ Laser Supervisor
3. Annual refreshers

B. Basic Policy

1. Only Authorized Users may use Class 3B and 4 lasers without supervision.
   1. *Must be SFSU enrolled students, current employees, or current "volunteer employees" (Post-docs and visiting students or faculty, contact dept. office)*
   2. *Must be formally "registered" as a "New Laser Operator"*
   3. *Have completed laser safety awareness training with the Laser Safety Officer*
   4. *Received documented on- the- job operational training (OTJ) on the laser*
   5. *Signed New Operator Registration and OTJ forms on file with LSO.*
2. Post sign or turn on signal light to notify that the laser is in use and restrict access to authorized and trained personnel.
3. Laser beams may not be pointed at entrance ways or in anyone's eyes
4. Only trained and authorized technician may perform maintenance or repairs