LASER SAFETY TRAINING

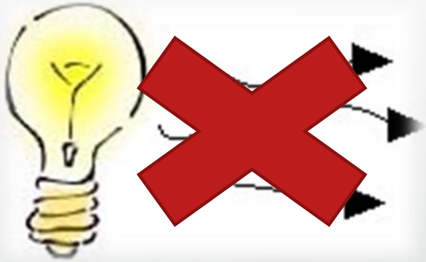
BARTU ŞİMŞEK

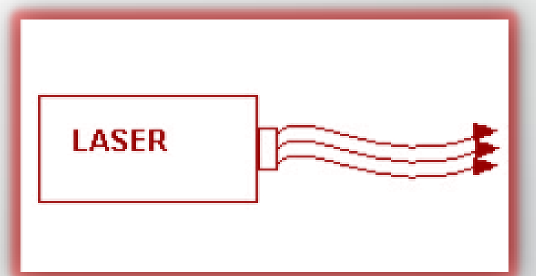
CONTENT

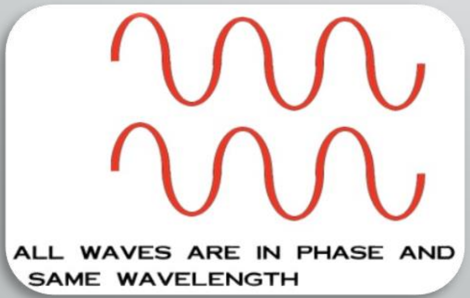
- Characteristics of Laser Light
- Laser Hazards – Beam Hazards
- Laser Hazards – Non Beam Hazards
- Safety Standards
- Maximum Permissible Exposure (MPE)
- Laser Hazards Classification
- The Laser Safety Officer (LSO)
- Controlling Laser Hazards
- Summary

Characteristics of Laser Light

- **Monochromatic**
  - One color/wavelength
- **Directional**
  - Narrow beam in a spesific direction
- **Coherent**
  - Wavelengths of the laser light are in phase in space and time.





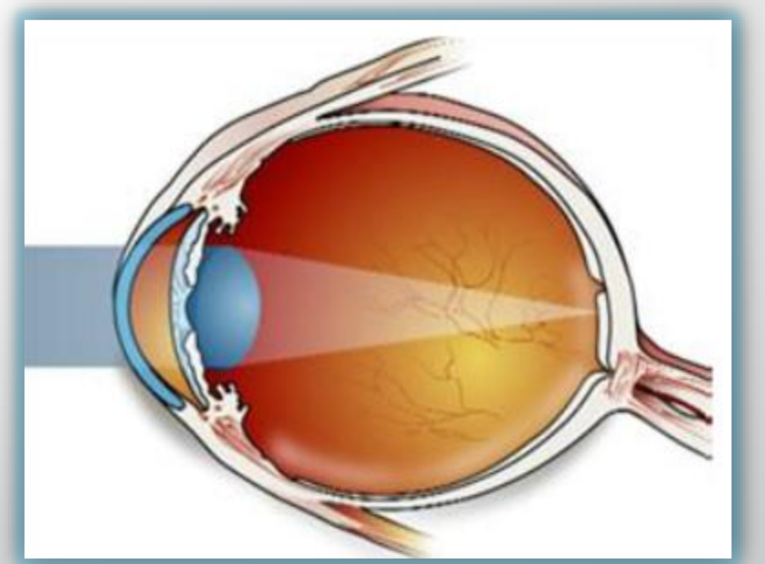


These three properties of laser light are what can make it more hazardous than ordinary light. Laser light can deposit a lot of energy within a small area.

LASER HAZARDS – BEAM HAZARDS

EYE INJURIES

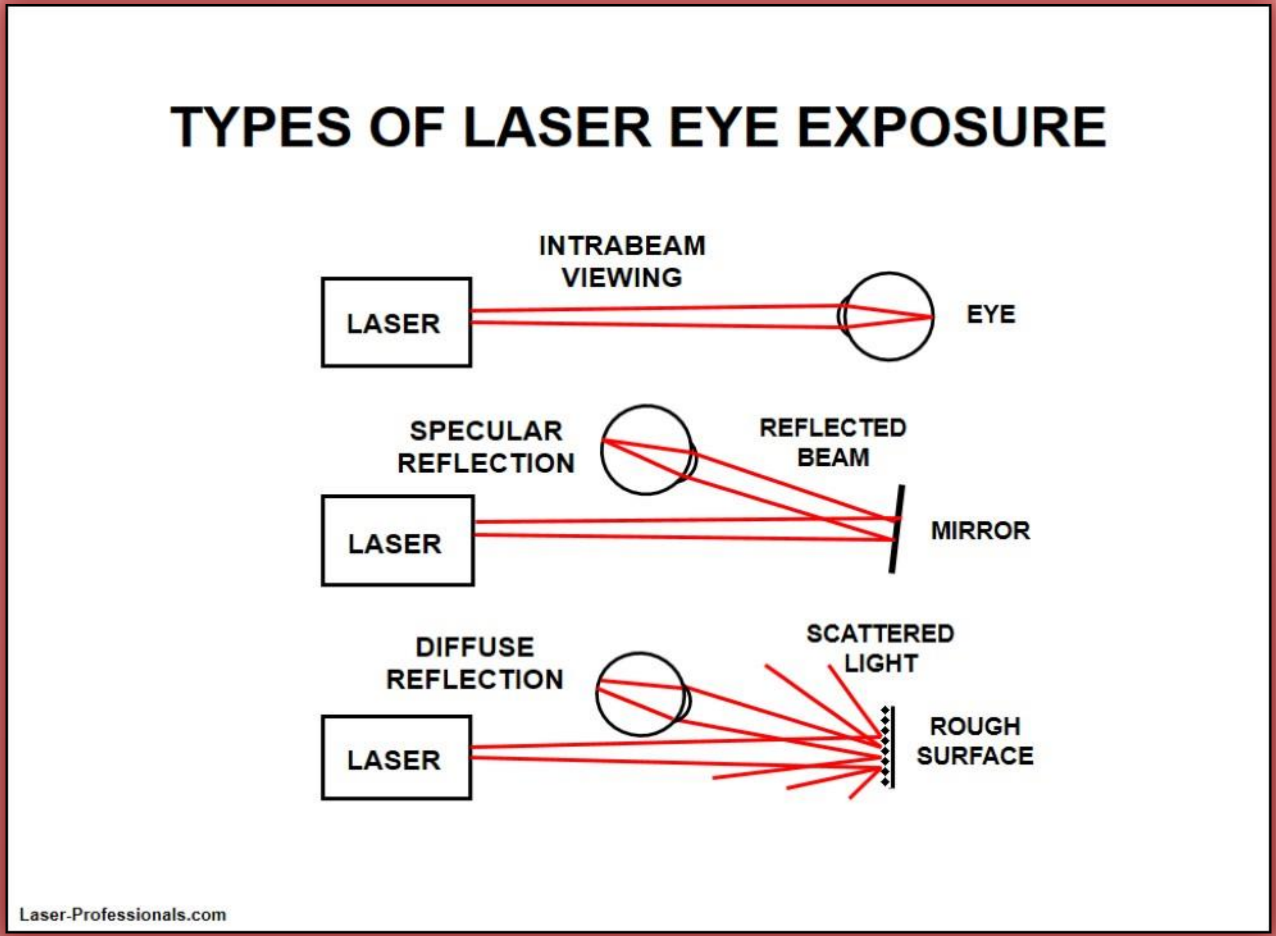
- Acute exposure of the eye to lasers of certain wavelengths and power can cause corneal or retinal burns (or both). Chronic exposure to excessive levels may cause corneal or lenticular opacities (cataracts) or retinal injury.



http://www.lia.org/media/osha/player.php

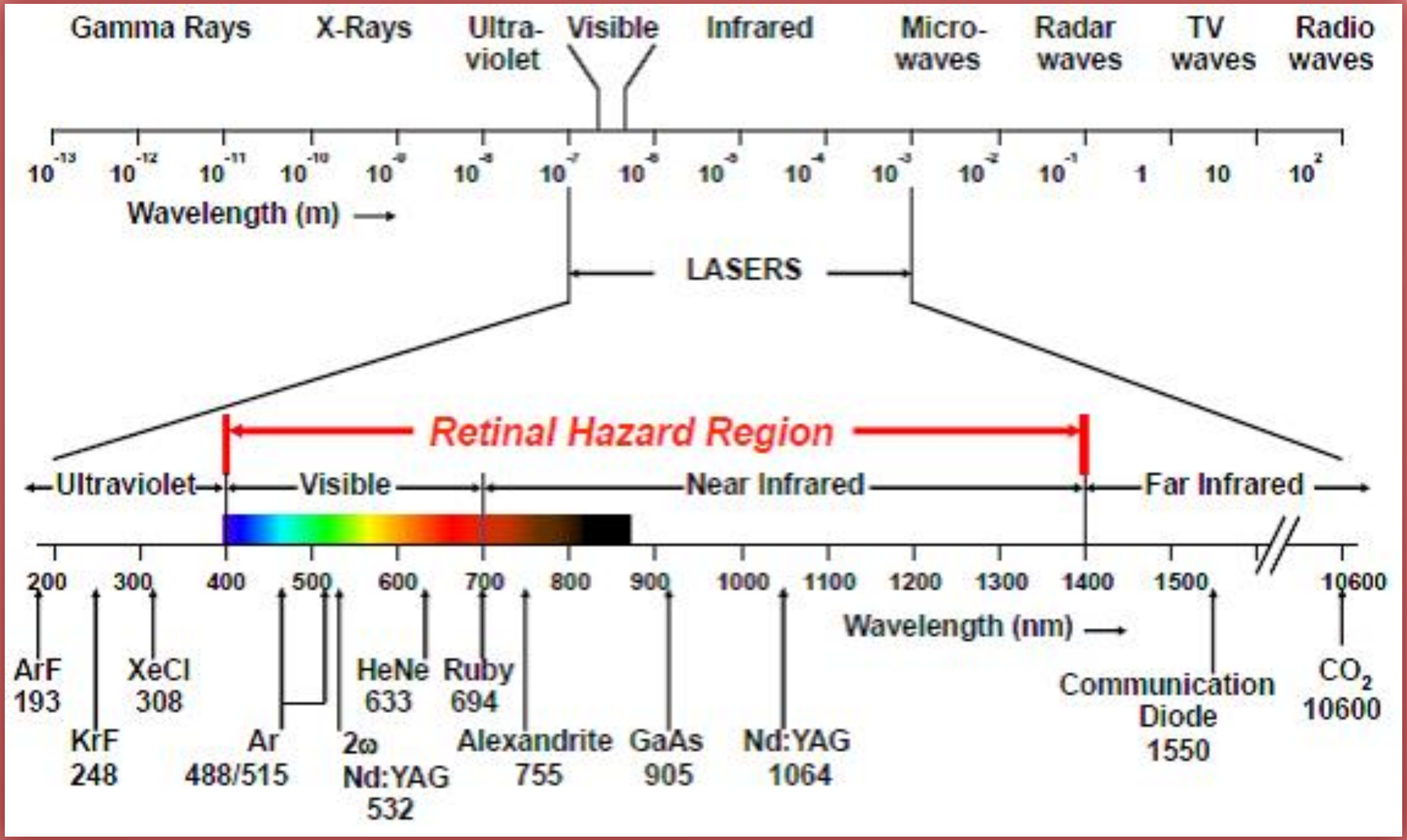
LASER HAZARDS – BEAM HAZARDS

EYE INJURIES



LASER HAZARDS – BEAM HAZARDS

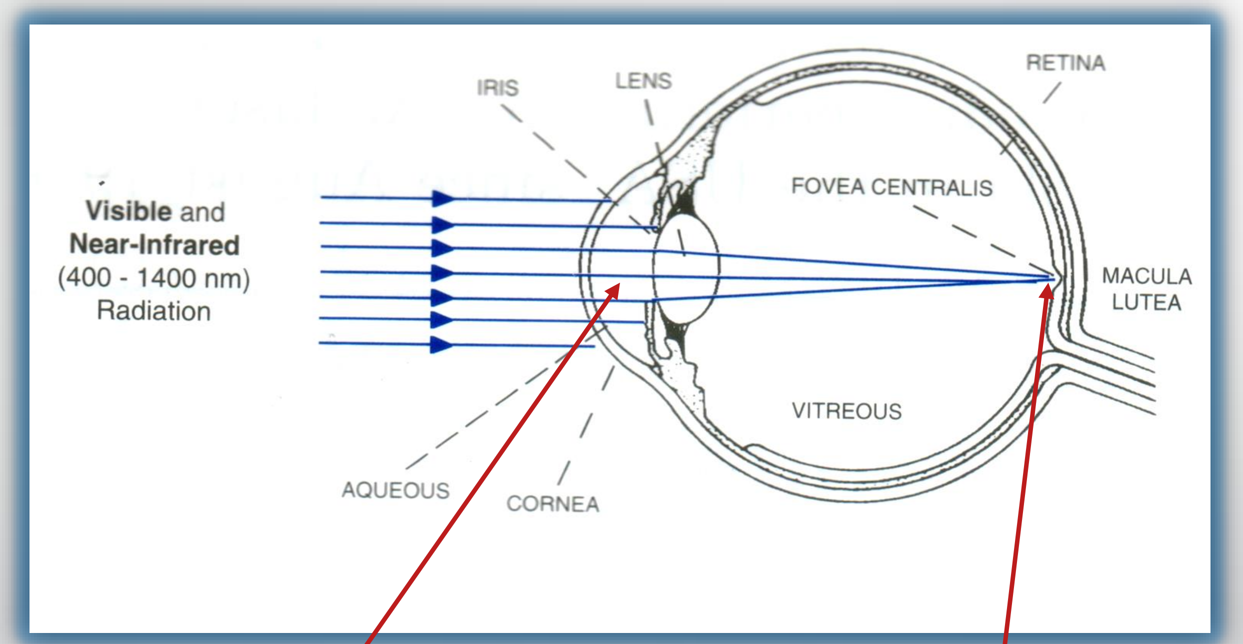
EYE INJURIES



http://www.cpsafety.net/wp-content/uploads/2014/02/Image-1.png

LASER HAZARDS – BEAM HAZARDS

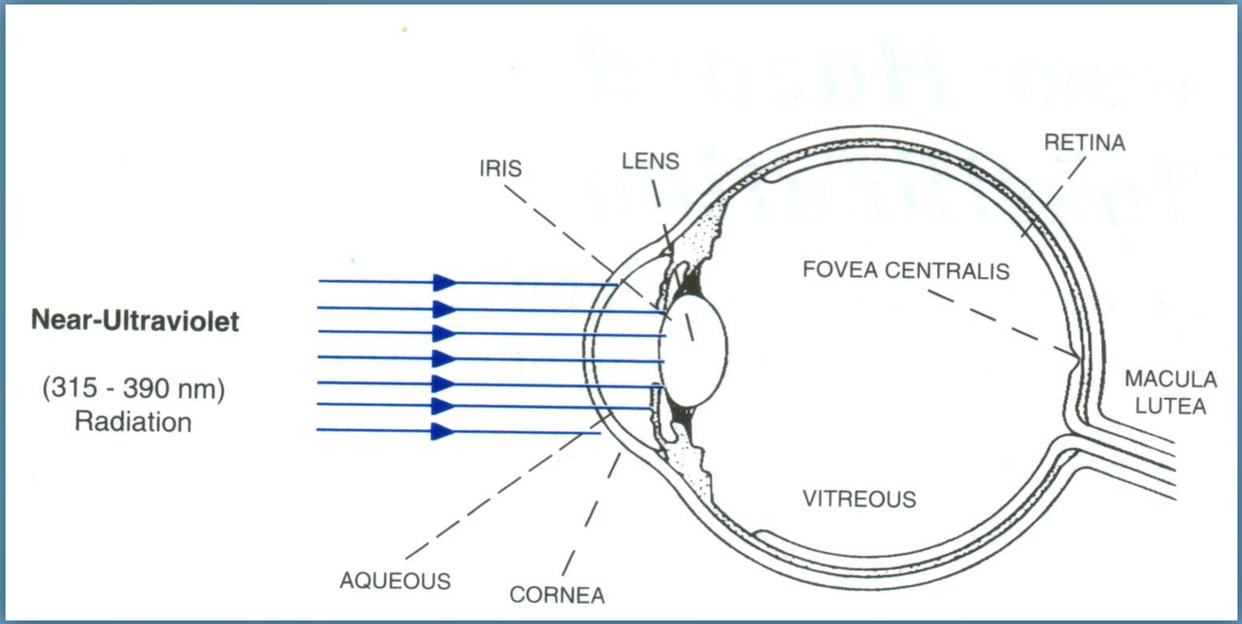
EYE INJURIES



- Normal focusing of the eye amplifies the irradiance by approximately 100,000; thus, a beam of 1 mW/cm2 results in an exposure of 100 W/cm2 to the retina.
- Eye can focus a collimated beam of light to a spot 20 microns in diameter on the retina (Focal Point).
- Visible and Near-Infrared Radiation causes Retinal burn.

LASER HAZARDS – BEAM HAZARDS

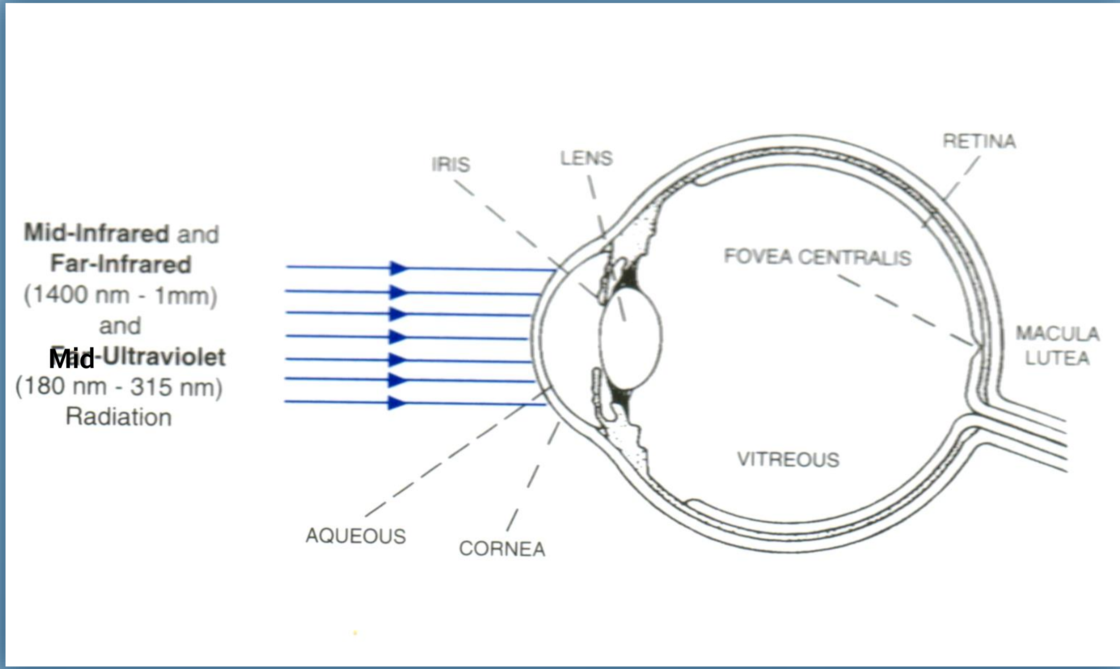
EYE INJURIES



- Near Ultraviolet – Contributes to certain forms of cataracts
- Xenon Chloride Excimer: Instant cataract, 308 nm pulsed laser

LASER HAZARDS – BEAM HAZARDS

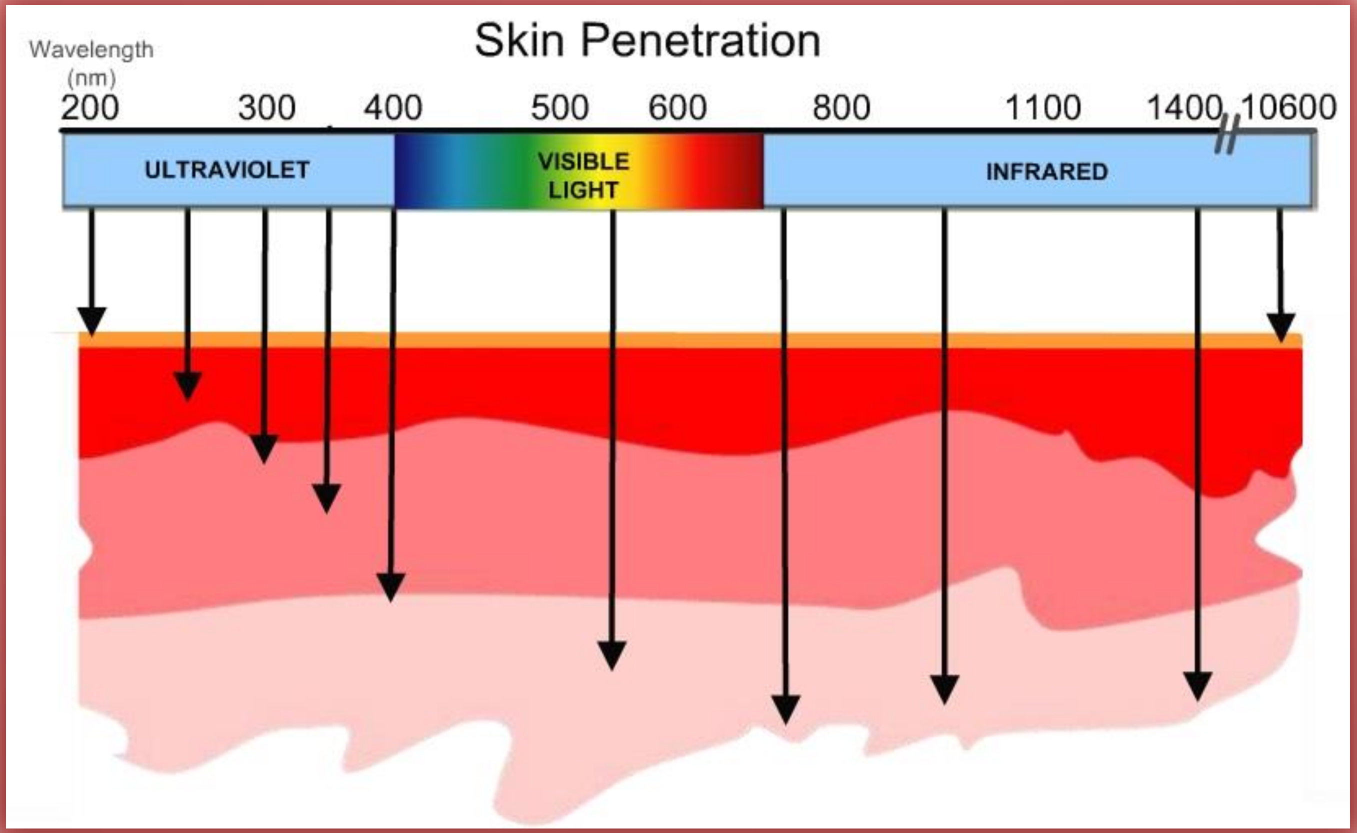
EYE INJURIES



- Mid and Far Infrared - causes damage to the cornea by increased temperature in tears and tissue water.
- Mid Ultraviolet – causes photokeratitis (welders flash)

LASER HAZARDS – BEAM HAZARDS

SKIN INJURIES



http://www.lia.org/media/osha/player.php

LASER HAZARDS – BEAM HAZARDS

SKIN INJURIES

Photobiological Spectral Domain		Eye Effects	Skin Effects
Ultraviolet C	200 - 280 nm	Photokeratis	Erythema (sunburn) Skin Cancer
Ultraviolet B	280 - 315 nm		Accelerated Skin Aging, Increased Pigmentation
Ultraviolet A	315 - 400 nm	Photochemical UV cataract	Pigment Darkening
Visible	400 - 780 nm	Photochemical & Thermal Retinal Injury	Photosensitive Reactions
Infrared A	0.78 - 1.4 µm	Cataract & Retinal Burns	Skin Burns
Infrared B	1.4 - 3.0 µm	Corneal Burn & Aqueous Flare & IR Cataract	
Infrared C	3.0 - 10.0 µm	Corneal Burn Only	

http://www.lia.org/media/osha/player.php

LASER HAZARDS – NONBEAM HAZARDS

INDUSTRIAL HYGIENE	• Compressed gases • Cryogenic materials • Toxic and carcinogenic materials • Noise
EXPLOSION HAZARDS	• High-pressure arc lamps • Filament lamps
NONBEAM RADIATION HAZARDS	• Radio frequency (RF) energy associated with some plasma tubes. • X-ray emission associated with the high voltage power supplies used with excimer lasers.

LASER HAZARDS – NONBEAM HAZARDS

COLLATERAL RADIATION

- Ultraviolet radiation emitted from laser discharge tubes, pumping lamps

ELECTRICAL HAZARDS

- Electrical installation and connection to the power supply circuit

FLAMMABILITY OF LASER BEAM ENCLOSURES

- Enclosure of Class IV laser beams and terminations of some focused Class IIIB lasers, can result in potential fire hazards if the enclosure materials are exposed to irradiances exceeding 10 W/cm2.

LASER SAFETY STANDARDS

DOL / OSHA

Occupational Safety and Health Administration

OSHA

Construction – 29 CFR 1926.54

General Duty Clause

Public Law 91-596: OSHA ACT

http://www.lia.org/media/osha/player.php

LASER SAFETY STANDARDS

ANSI Z136.1

ANSI Z136.1
For Safe Use of Lasers

Parent Document in the Z136 Series

- Provides İnformation On:
  - Exposure Limits
  - Hazard Classification
  - Calculations And Measurements
  - Control Measures
  - Laser Safety Officers
  - Laser Safety Programs

LASER SAFETY STANDARDS

FDA / CDRH

Center for Devices and Radiological Health

CDRH

Applicable to Manufacturers of Laser Products

Federal Laser Product Performance Standard

MAXIMUM PERMISSIBLE EXPOSURE (MPE)

«Safe Exposure Limit»

- **The level of laser radiation to which a person may be exposed without hazardous effect or adverse biological changes in the eye or skin.**

- Ocular MPE generally lower than Skin MPE

- MPE is used to determine:
  - Nominal Hazard Zone (NHZ)
  - Optical Density (OD)
  - Accesible Emission Limit (AEL)

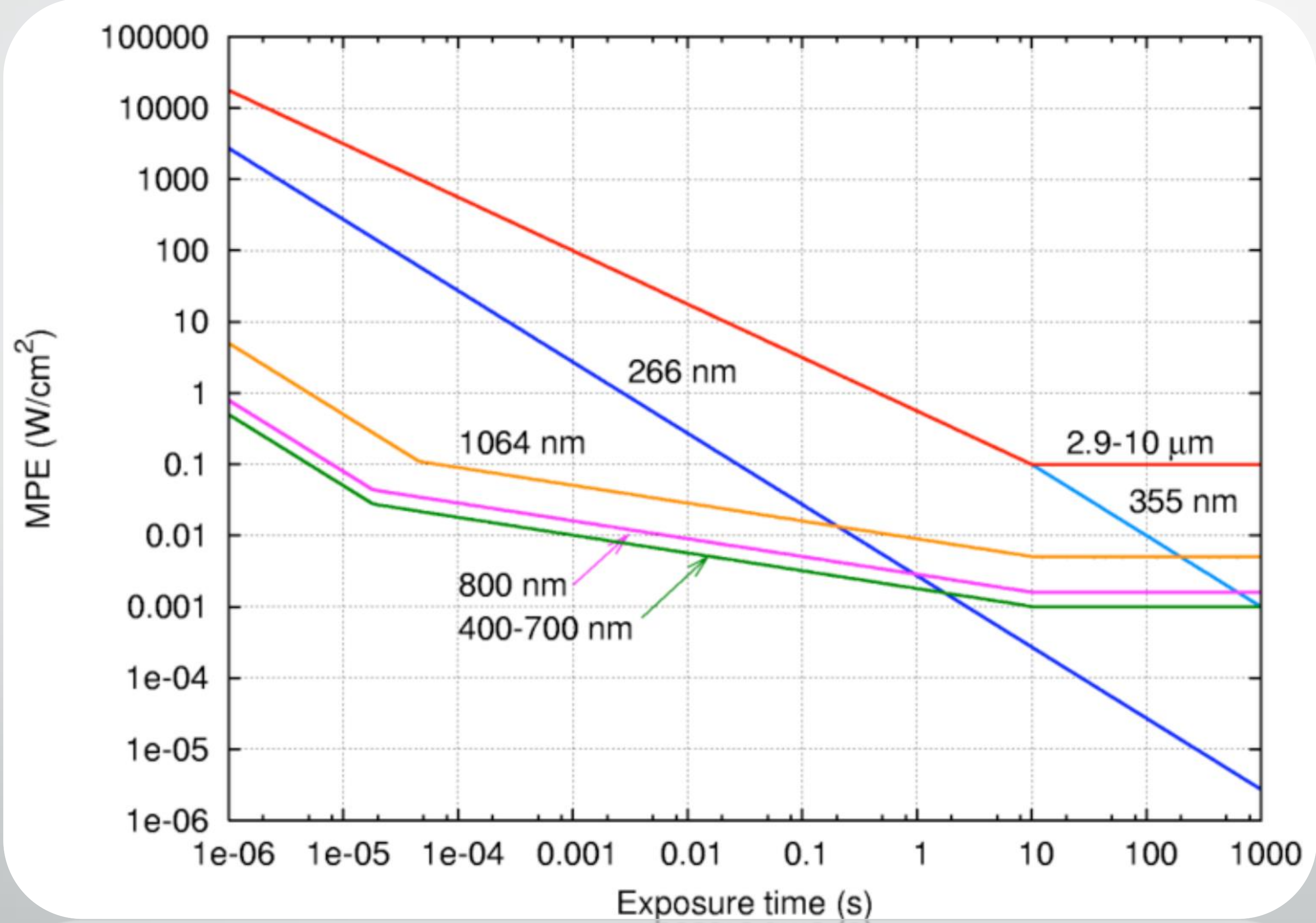
MAXIMUM PERMISSIBLE EXPOSURE (MPE)

- The primary factors that effect the MPE are:
  - The exposure type (Intrabeam eye exposure is the worst case.)
  - The laser wavelength
  - The pulse characteristics of the laser output
  - Exposure duration

- An exposure duration of 0.25 s is usually used for an accidental exposure to a visible laser. An exposure duration of 10 s is usually used for an invisible laser.

http://lasersafetyu.kentek.com/easy-haz-laser-hazard-software-basic-web-version/

MAXIMUM PERMISSIBLE EXPOSURE (MPE)

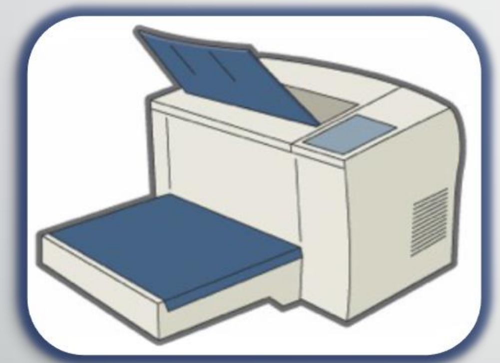


http://en.wikipedia.org/wiki/image:ICE60825_MPE_W_s.png

LASER HAZARDS CLASSIFICATION

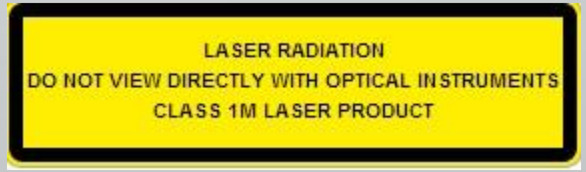
CLASS 1 LASERS

- This class is eye-safe under all operating conditions.
- Class 1 laser is safe for use under all reasonably anticipated conditions of use.



CLASS 1M LASERS

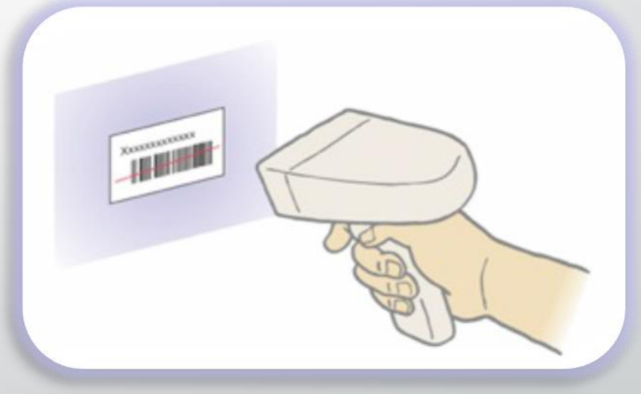
- «M» is for Magnification.
- A Class 1M laser is safe for all conditions of use except when passed through magnifying optics such as microscopes and telescopes.



LASER HAZARDS CLASSIFICATION

CLASS 2 LASERS (US 2a)

- Staring into beam is eye hazard
- Eye is protected by the blink reflex that limits the exposure to no more than 0.25 seconds.
- Only applies to visible-light lasers (400-700 nm).
- CW maximum power 1mW



CLASS 2M LASERS (US 2b)

- «M» is for Magnification.
- A Class 2M laser is safe because of the blink reflex if not viewed through optical instruments .

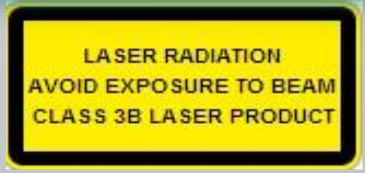
LASER HAZARDS CLASSIFICATION

CLASS 3R LASERS (US 3A)

- A Class 3R laser is considered safe if handled carefully, with restricted beam viewing.
- Aversion response may not provide adequate eye protection.
- The CW power is limited to 5 Mw (visible).
- The ANSI Standard has the same limits for visible and invisible lasers.
- CRDH standards allows only visible in class 3a.

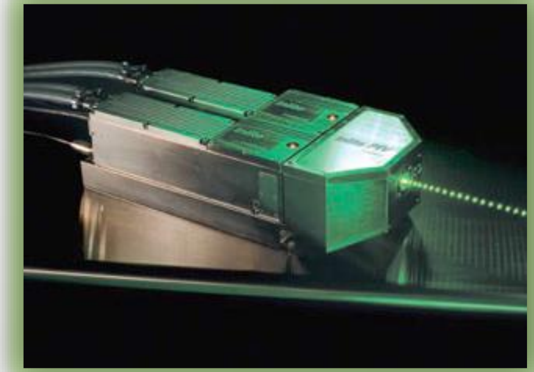
CLASS 3B LASERS (US 3B)

- A Class 3B laser is hazardous if the eye is exposed directly, but diffuse reflections such as those from paper or other matte surfaces are not harmful.
- CW maximum power 500 mW.



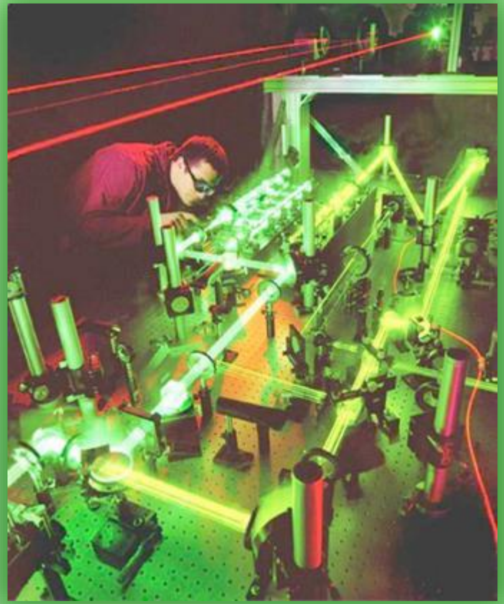
LASER HAZARDS CLASSIFICATION

CLASS 4 LASERS (US 4)



- 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 skin from the direct beam and specular reflections. Even a diffuse reflection can cause injury.

- This class of laser can cause fires.
- Class 4 lasers must be equipped with a key switch and a safety interlock.
- Requires a Laser Safety Officer and written Standard Operating Procedures.



LASER SAFETY OFFICER

LSO

ANSI Z.136.1 specifies for all circumstances of operation, maintenance, and service of a Class 3B or 4 laser or laser system an LSO shall be designated.

- The LSO must:
  - Have the authority and responsibility to monitor and enforce the control of laser hazards.
  - Be responsible for evaluation of laser hazards and establishment of appropriate control measures.
  - Be provided the appropriate training to properly establish and administer a laser safety program.

LASER SAFETY OFFICER

LSO

Duties of the Laser Safety Officer may include:

- Oversee safety for all operational, maintenance, and servicing situations.
- Hazard evaluation and establishment of hazard zones.
- Control measures and compliance issues.
- Approval of Standard Operationg Procedures and maintence/service procedures.
- Approval of equipment and installations.
- Safety training for laser personnel.
- Recommendation and approval of personal protective equipment, and other administrative responsibilities.

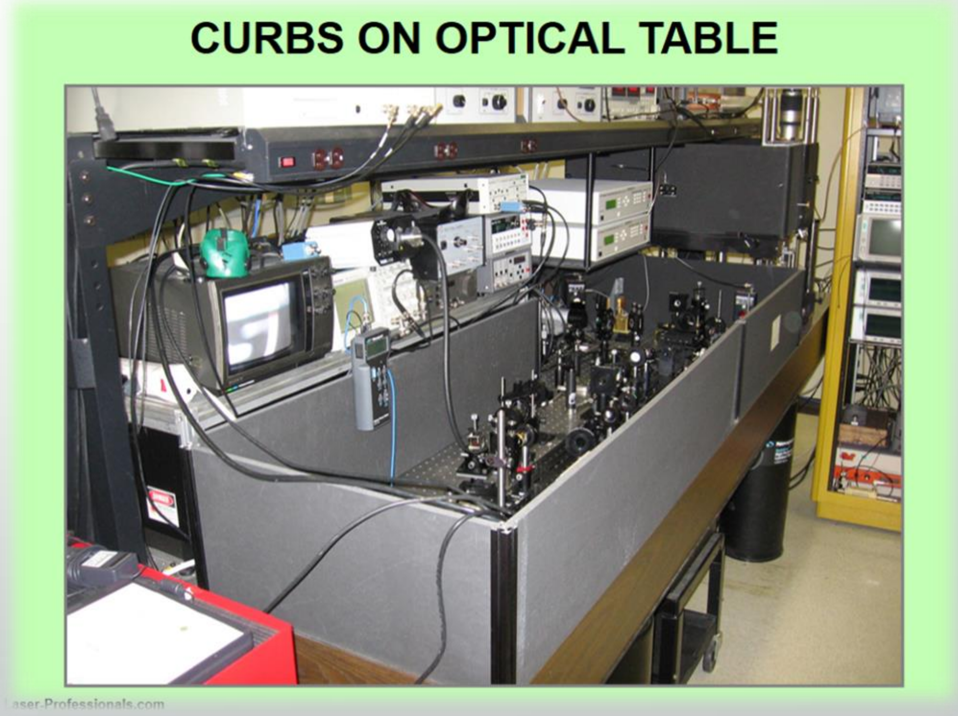
CONTROLLING LASER HAZARDS

ENGINEERING

- **Engineering** controls are features built into the equipment or facility that protect personnel *automatically without the need of protective action on the part of the worker*.

CONTROLLING LASER HAZARDS

ENGINEERING



CONTROLLING LASER HAZARDS

ENGINEERING

BEAM CONTROL

EMERGENCY SYSTEM

CONTROLLING LASER HAZARDS

ADMINISTRATIVE / PROCEDURAL

- **Standard Operating Procedures (SOPs)**

LaserSafetySOP.pdf

- **Education & Training**

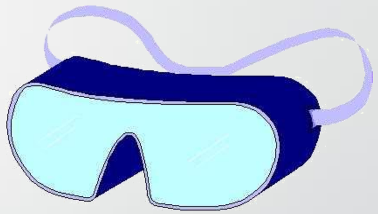
- **Personal protective equipment**
  - Laser Safety Eyewear

CONTROLLING LASER HAZARDS

ADMINISTRATIVE / PROCEDURAL

Laser Safety Eyewear

- Laser safety eyewear is available in glass or plastic for all laser wavelengths.
- The required Optical Density of the eyewear is determined in the hazard analysis performed by the LSO.
- **Optical Density**



$OD = \log_{10} \dfrac{H_0}{MPE}$

H_0 = Anticipated worst-case exposure (J/cm^2 or W/cm^2)

MPE = Maximum permissible exposure level expressed in the same units as H_0

Example:
The minimum optical density at a 0.514 μm argon laser wavelength for a 600-second direct intrabeam exposure to the 5-watt maximum laser output can be determined as follows:

Where:

H_0 = [Power/Area] = ϕ/A = $4\phi/\pi d^2$

= $[(4)(5.0)/\pi(0.7)^2]$

= 12.99 W/cm^2

Computing the worst-case exposure H_0:

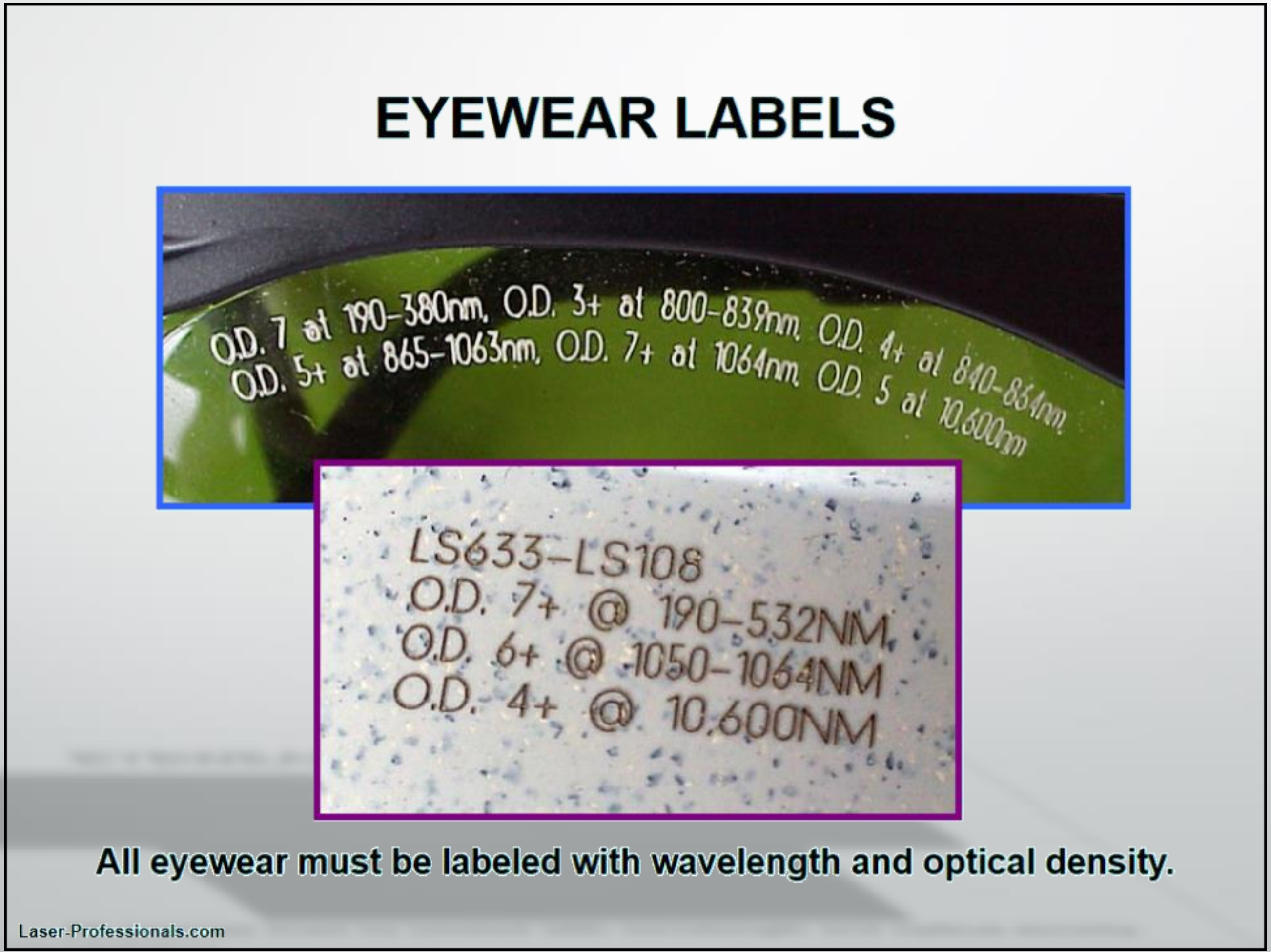
Power = 5 Watts

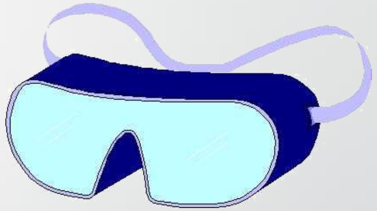
MPE = *16.7 W/cm^2 (using 600-second criterion)

Distance = 7 mm (worst-case pupil size)

CONTROLLING LASER HAZARDS

ADMINISTRATIVE / PROCEDURAL





The 10 Golden Rules of Laser Safety

Do not look into a laser beam.

Don't look down specular reflections (e.g.: from mirrors or other reflective surfaces).
Don't stare at diffuse reflections.
If it looks bright-don't stare at it.

Keep room lights on brightly if possible.

The brighter the ambient lighting level, the smaller the eye's pupil will become, and the chance of a laser beam entering the eye will be lessened.

Remove personal jewellery.

Watches, rings etc. act as reflectors. When entering a laser lab, remove anything whichmay pose a refection hazard. This is to protect you and your co-workers.

Locate and terminate all stray laser beams.

Make sure that all stray beams are terminated with a matt, diffusing beam dump which is capable of handling the power of the laser beam.

Clamp all optical components securely.

Clamp, and where possible double clamp all optical components; this helps prevent your experiment from becoming misaligned and reduces the chances of a component moving and sweeping a laser beam over you.

The 10 Golden Rules of Laser Safety

Keep beams horizontal.

Horizontal beams are easier to work with and are predictable. Avoid vertical and skew beams if possible. Change beam height with a periscope, and be careful when aligning it.

Don't bend down below beam height.

If you drop something, block the laser beam at the laser before picking the object up. If you can't stop the beam (for instance, if you are in the middle of an experimental run), kick the object out of the way so that you don't trip over it. If you must sit down in a lab, make sure that the chair is high enough that your head is above beam height. If, for one reason or an other, you have to bend down, close your eyes when doing so or protect them with your hands.

The 10 Golden Rules of Laser Safety

Remember, optical components refect, transmit and absorb light.

Often, a transmitting component will also reflect light, a reflecting component will transmit light etc..

Don't forget non-optical hazards.

Don't trip over, electrocute yourself, spill solvents,burn yourself on liquid nitrogen etc..

Wear laser safety eyewear.

If eyewear is provided, ensure that it is suitable and wear it. Remember: laser radiation can be invisible, so just because you don't see anything that does not mean that there is nothing !

EXTRA INFORMATION

ALIGNMENT GUIDELINES FOR CLASS 3b AND 4 LASERS

1. Exclude unnecessary personnel from the laser area during alignment.
2. Where possible, use low-power visible lasers for path simulation of high power visible or invisible lasers.
3. Wear protective eyewear during alignment. Use special alignment eyewear when circumstances permit their use.
4. When aligning invisible beams, use beam display devices such as image converter viewers or phosphor cards to locate beams.
5. Perform alignment tasks using high-power lasers at the lowest possible power level.
6. Use a shutter or beam block to block high-power beams at their source except when actually needed during the alignment process.
7. Use a laser rated beam block to terminate high-power beams downstream of the optics being aligned.
8. Use beam blocks and/or laser protective barriers in conditions where alignment beams could stray into areas with uninvolved personnel.
9. Place beam blocks behind optics to terminate beams that might miss mirrors during alignment.
10. Locate and block all stray reflections before proceeding to the next optical component or section.
11. Be sure all beams and reflections are properly terminated before high-power operation.
12. Post appropriate area warning signs during alignment procedures where lasers are normally class 1.
13. Alignments should be done only by those who have received laser safety training.

EXTRA INFORMATION

SAFE WORK PRACTICES

- Never intentionally look directly into a laser. Do not stare at the light from any laser. Allow yourself to blink if the light is too bright.
- Do not view a Class 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.
- 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.

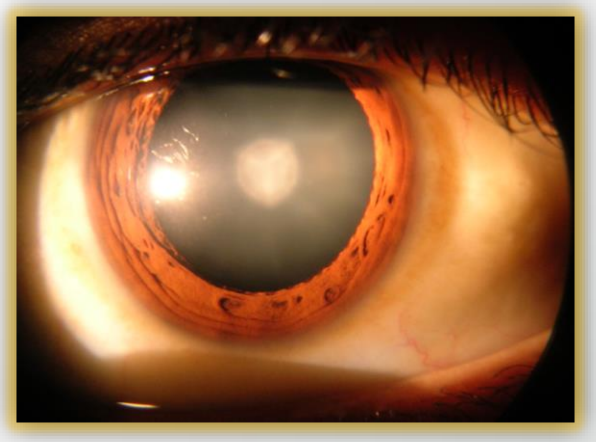
EXTRA INFORMATION

HyperpIgmentation : In dermatology, hyperpigmentation is the darkening of an area of skin or nails caused by increased melanin.

Erythema: is a skin condition characterized by redness or rash. There are many types of erythema, including photosensitivity, erythema multiforme, and erythema nodusum.

EXTRA INFORMATION

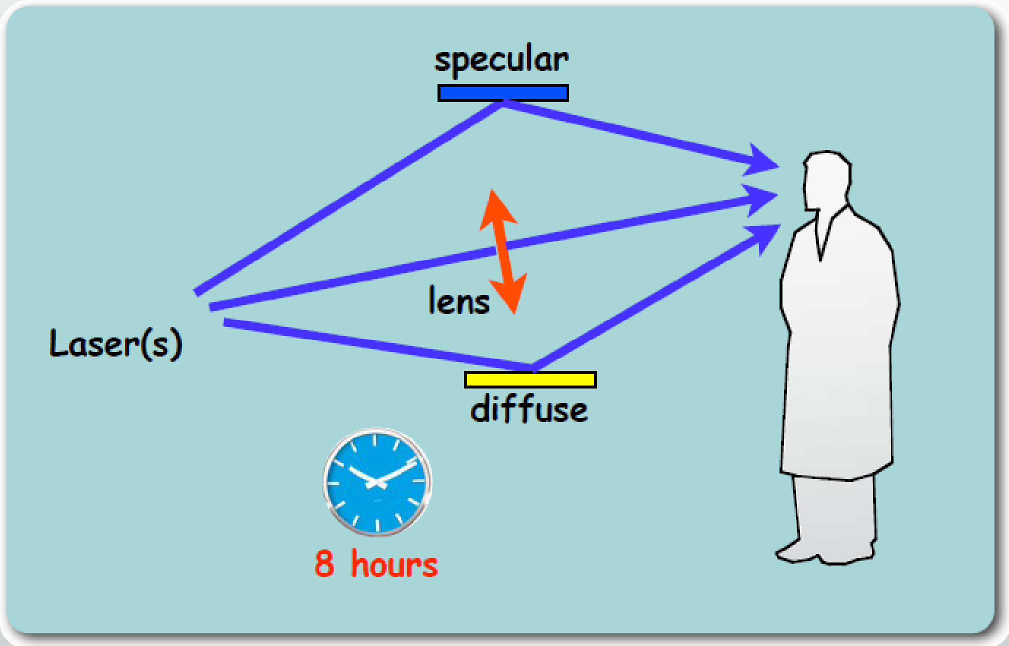
Cataract is a clouding of the lens inside the eye which leads to a decrease in vision. It is the most common cause of blindness and is conventionally treated with surgery.



Photokeratitis or **ultraviolet keratitis** is a painful eye condition caused by exposure of insufficiently protected eyes to the ultraviolet (UV) rays from either natural or artificial sources. Photokeratitis is akin to a sunburn of the cornea and conjunctiva, and is not usually noticed until several hours after exposure.

EXTRA INFORMATION

Nominal Hazard Zone (NHZ): The nominal hazard zone describes the space within which the level of the direct, reflected or scattered radiation during operation exceeds the applicable MPE. Exposure levels beyond the boundary of the NHZ are below the applicable MPE level.



Laser type:	specified
Output power:	specified
Exposure time:	specified
Illumination situation:	specified

→ NHZ [m]