*Secretariat and publisher of*
Z136 Series of Laser
Safety Standards

***Celebrating***
***44 years of***
***service to the***
***laser community***

**Laser Institute**
**of America**

Founded in 1968, the LIA is celebrating 44 years of service to the laser community. The LIA is dedicated to fostering lasers, laser applications and laser safety worldwide. LIA accomplishes this mission through publications, conferences, symposia, and educational courses.

Laser Institute of America

# Laser Safety Training

# OSHA

Asheboro, NC
October 30, 2012

13501 Ingenuity Dr., Suite 128 • Orlando, FL 32826
800.345.2737 • Fax: 407.380.5588
www.LIA.org

# Laser Safety Training
# Course Notes

# *Quantum Jump*

This work sponsored in part by the Laser Institute of America's "Quantum Jump" program. Quantum Jump is supported by contributions from many LIA Individual Members and the following founding Corporate Sponsors:

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# Laser Safety Training

LIA and OSHA Alliance

## Laser Institute of America Mission Statement

"The Laser Institute of America is the non-profit membership society dedicated to fostering lasers, laser applications and laser safety worldwide"

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## Course Objectives

1. Identify the 4 hazard classes of lasers
2. Determine who is authorized and given the responsibility to monitor and implement a laser safety program
3. Be able to identify if a company has a laser safety program
4. Identify control measure for beam and non-beam hazards

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# How are Lasers Classified?

Section 1

## Questions to Ask

- Question 1: What class of laser(s) are used?
- Rationale: Sets the level of controls that need to be in place according to ANSI Z136.1 standard.

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## Laser Hazard Classification Scheme ANSI Z136.1

- Class 1 (Exempt)
  - Incapable of producing damaging radiation levels during operation
  - Exempt from any control measure
- Example
  - Completely enclosed machine with higher powered laser inside

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# Laser Hazard Classification Scheme ANSI Z136.1

- Class 1M
  - Incapable of producing damaging radiation levels during operation
  - **Unless** the beam is viewed with an optical instrument
    - Eye-loupe or telescope
  - Exempt from any control measure other than to prevent potentially hazardous optically aided viewing
- Example
  - Fiber optic communication systems

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# Laser Hazard Classification Scheme ANSI Z136.1

- Class 2 (Low power)
  - visible (400-700 nm)
  - eye protection is aversion response
  - CW upper limit is 1 mW
- Examples
  - Supermarket or barcode scanners

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# Laser Hazard Classification Scheme ANSI Z136.1

- Class 2M
  - visible (400-700 nm)
  - eye protection is aversion response for unaided viewing
  - Potentially hazardous when viewed with optical aid
  - CW upper limit is 1 mW
- Examples
  - Leveling instruments and some construction industry lasers

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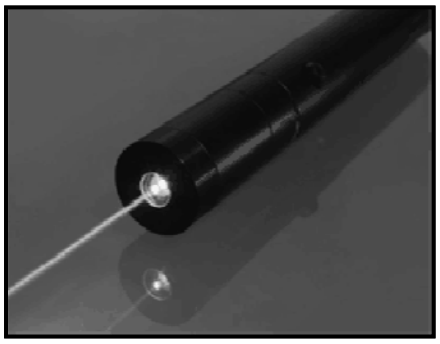
# Laser Hazard Classification Scheme ANSI Z136.1



- Class 3R
  - "R" stands for Reduced Requirements
  - Potentially hazardous under some direct and specular reflection
  - Eye must be focused and stable
    - Probability of injury is small
  - Does not pose diffuse-reflection or fire hazard
  - Simply replacing 3a
- Example
  - Laser pointer

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# Laser Hazard Classification Scheme ANSI Z136.1

- Class 3B
  - Operate between 5mW and 500mW
  - Normally not a fire or diffuse viewing hazard
  - Hazardous under direct and specular reflection viewing
- Examples
  - Some military lasers, lasers used in therapeutic medicine, some research lasers

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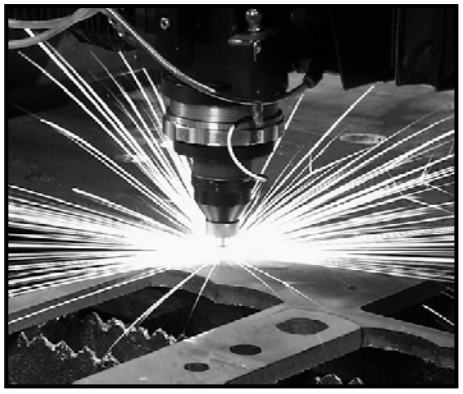
# Laser Hazard Classification Scheme ANSI Z136.1



- Class 4
  - hazardous to eye and skin from direct viewing, specular and diffuse reflections
  - fire hazard
  - may produce laser generated air contaminants
  - may produce hazardous plasma radiation
- Examples
  - Lasers used for cutting, drilling, marking, welding materials, entertainment and surgical lasers

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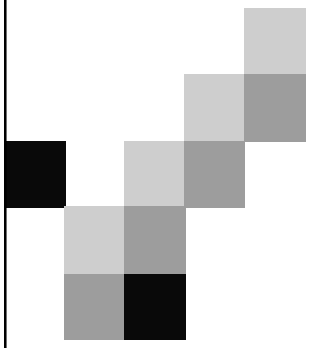

# What is the USA Laser Safety Standard?

## Section 2

## Questions to Ask

- Question 2: Do you have a copy of ANSI Z136.1 *Safe Use of Lasers* standard?
- Rationale: This document is the core of any laser safety program. At least one copy should be onsite and available to employees.

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# ANSI Z136.1-2007 for Safe Use of Lasers

- Principal U.S. safety standard
- Began in 1969 at request of US. Department of Labor
- April 26, 1973, final document approved
- Revised in 1976, 1980, 1986, 1993, 2000, 2007
- Referred to as ANSI Z136.1-2007


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# American National Standard for Safe Use of Lasers

- Laser Institute of America has been Secretariat and Publisher since 1986
- Responsible for organizing the Consensus Committees
  - industry
  - government
  - public sectors

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## ANSI Z136.1: What Type of Standard?

- Z136.1 is a "national consensus standard"
- It is Voluntary
- It is not regulatory nor legally binding

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## ANSI Z136.1: What Type of Standard?

- To be able to say "our organization is in compliance with" or "conforms with" ANSI Z136.1 means:
  - You follow those mandatory requirements that are designated "***SHALL***"
  - You take into consideration advisory recommendations designated "***SHOULD***"
    - If they make sense in your application

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## Purpose of ANSI Z136.1-2007 for Safe Use of Lasers

- Provides recommendations for the safe use of lasers and laser systems between 180 nm and 1 mm
- Helps determine thresholds where radiant energy becomes a hazard
- Categorizes lasers into four basic hazard classes
- Specifies controls for each laser hazard class

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## Questions to Ask

- Question 3: Who is the Laser Safety Officer?

- Rationale: Required by ANSI Z136.1.

  You cannot have an effective laser safety program if there is not a properly trained LSO to oversee it.

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## Defines Role of Laser Safety Officer

- Laser Safety Officer (LSO)
  - Given responsibility and authority for safety program
  - In charge of monitoring and enforcement of hazard evaluation and control of laser hazards
  - "to effect" - LSO either performs task or ensures it is performed

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## Laser Safety Officer

- Laser Safety Officer
  - Required for Class 3B & 4 lasers
  - May be full or part-time position
    - Rarely a full time job
- ANSI Z136.1
  - Responsibilities in appendix A
  - Appendix A is normative

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## Questions to Ask

- Question 4: Do you have a Laser Safety Program in place? Can you show me?
- Rationale: Required by ANSI Z136.1.

  A documented program indicates thought has been given to laser safety and sets the programs requirements.

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# Where do you find Lasers?

Section 3

## Questions to Ask

- Question 5: What types of lasers do you have and what are they used for?
- Rationale: Gives indication of program awareness. If they don't know it's an indication of poor training.

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## Industrial Lasers are in:

- Manufacturing Facilities
- Job shops
- Automotive industry
- Aerospace industry
- Shipbuilders
- Bottling industry
- Tobacco industry
- Semiconductor manufacturers
- Cosmetic industry
- Food packaging industry
- Heavy equipment industry
- University and Research Facilities
- Clothing industry

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## Industrial Lasers

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## Industrial Lasers

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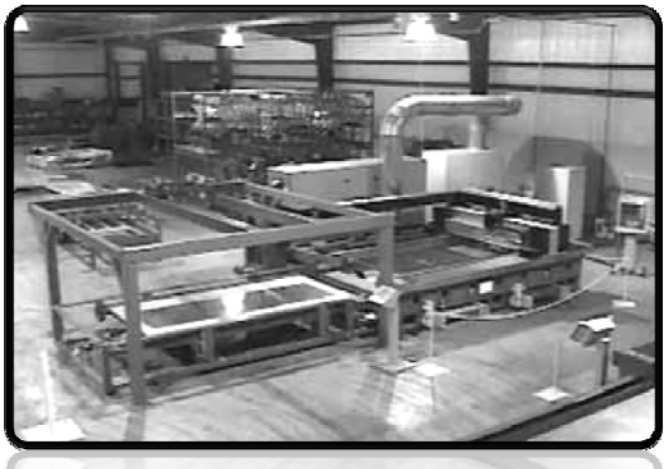
## Industrial Lasers



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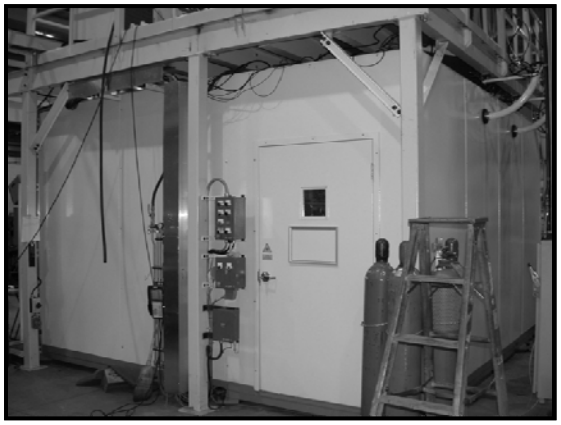
## Industrial Lasers



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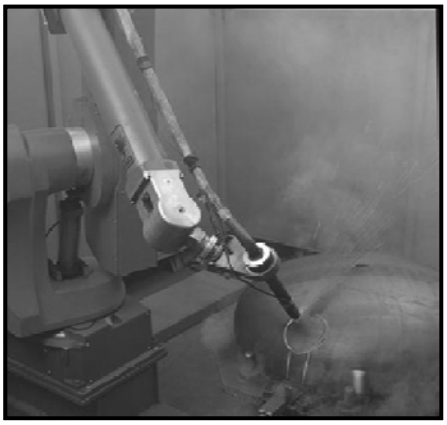
## Industrial Lasers



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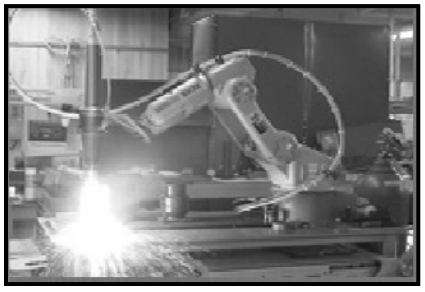
## Industrial Lasers



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## Industrial Lasers

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## Industrial Lasers


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# Industry Applications

- Cutting

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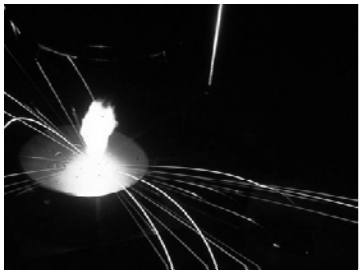
# Industry Applications

Drilling



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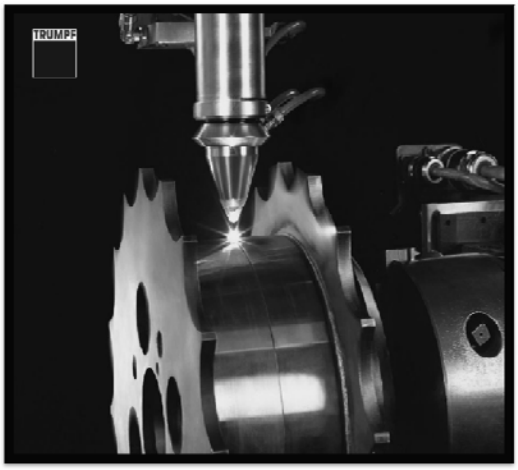
# Industry Applications

Welding

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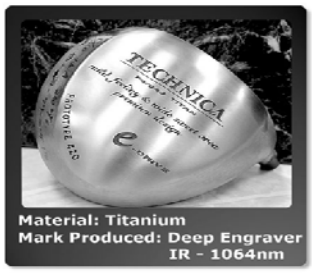
# Industry Applications

Marking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## Where are Research Lasers?

- Universities and Colleges
- R & D Labs
- Optics Companies
- Geology
- DOE
- Military

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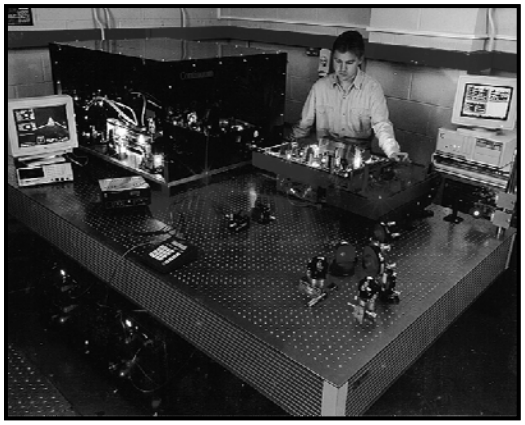
## Research Lasers



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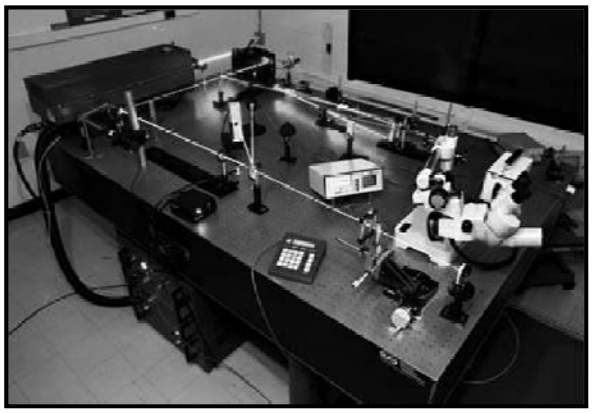
## Research Lasers



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## Research Applications

- Single molecule detection
- Spectroscopy
- Diagnostics
- Measurements

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## Research Applications Military

Direct energy weapon
Targeting
Tracking
Range finding

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## Where are Medical Lasers?

- Hospitals
- Clinics
- Outpatient/Surgery Centers
- MediSpas
- Ophthalmology
- Dermatology
- Veterinarians
- Dentists

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## Medical Lasers

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## Medical Lasers

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## Medical Lasers

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## Medical Lasers

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# Medical Applications

Ophthalmology

- Vision correction

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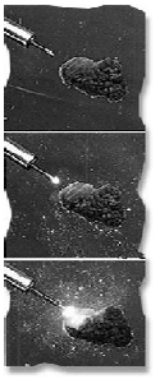
# Medical Applications

Urology

Cardiology

General surgery



Laser kidney treatment.

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## Medical Applications

### Dentistry

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## Medical Applications

### Veterinary

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## Medical Applications

### Hair Removal

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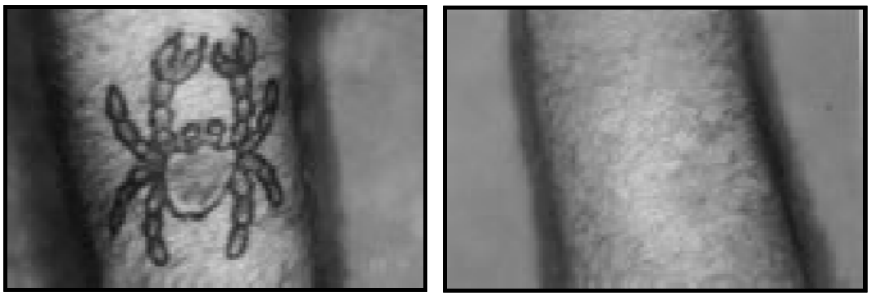
## Medical Applications

### Tattoo



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## Medical Applications

Skin
resurfacing

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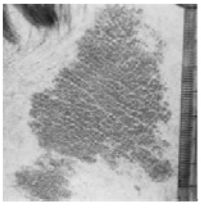
## Medical Applications

Port wine stain
removal

Vein treatments

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## Other Industries

- Communications
- Construction
- Entertainment
- Consumer

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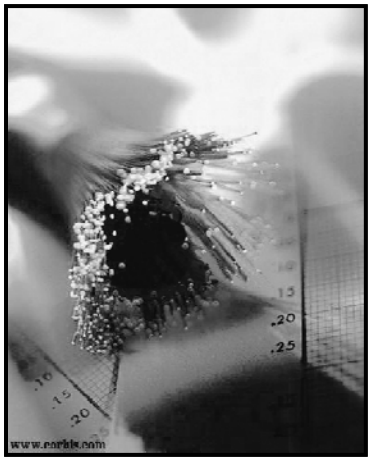
## Communications

Service providers



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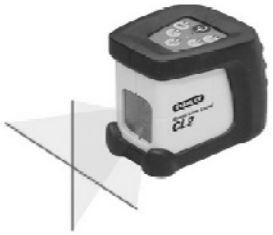
## Construction

Surveying

&

Leveling



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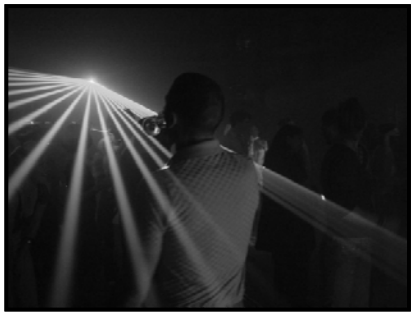
## Entertainment

Laser light shows



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## Most Common Lasers





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## Questions to Ask

- Question 6: Do you know where all the lasers are? Have them show you the inventory list.
- Rationale: Gives indication of control of program. Lasers tend to move around and they need to be tracked.

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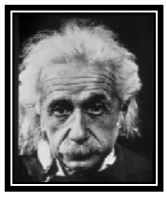
# What is a laser and How does it work?

## Section 4

## Laser History



**Einstein** – Theory of Stimulated Emission of Radiation. – 1917

**Arthur Schawlow and Charles Townes** Nobel prize for theory on "Optical Maser" based upon this theory of Stimulated Emission. – 1958

**Theodore Maiman** developed the 1st Laser – a Ruby Laser – in 1960 based upon Schawlow & Townes theory.

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## What is a Laser?

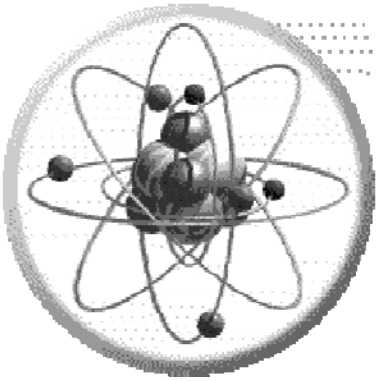
Light

Amplification

Stimulated

Emission of

Radiation



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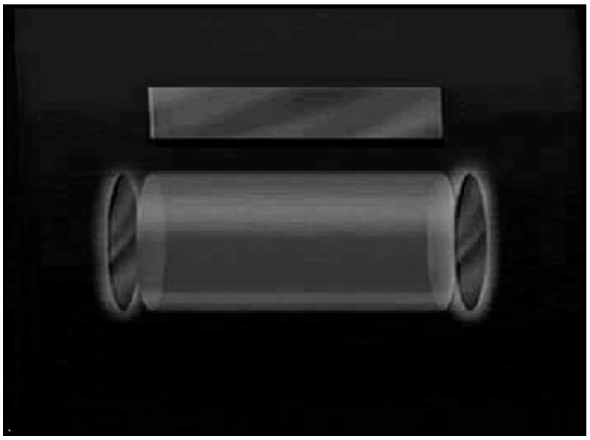
## Lasing Medium Together with the Excitation Mechanism



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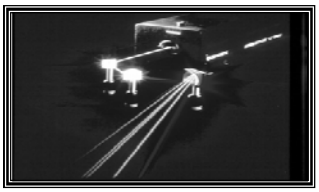
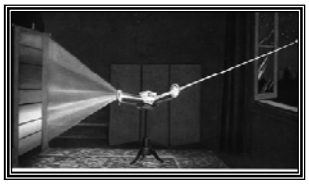
# Laser vs. Non-Laser


Monochromatic




Polychromatic



**Monochromatic:**
**beams of light are "pure" lines of color**

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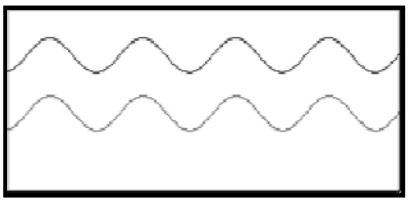
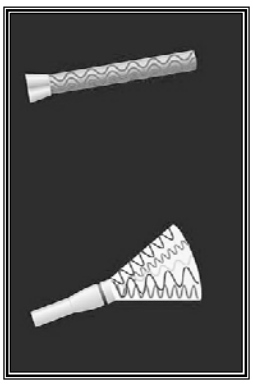
# Laser vs. Non-Laser

**Coherence**





**Light waves are in phase**

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# Laser vs. Non-Laser

Non-collimated

Collimated

Collimation allows for light to be focused to very small spot sizes

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# Directional

- Laser beams increase in size (diverge) very little over distance
- A typical laser will "grow" 1 mm every 1 meter traveled (or 1 m in 1 km)
- Such a beam is said to have a 1 milliradian divergence


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# What does this have to do with Laser safety?

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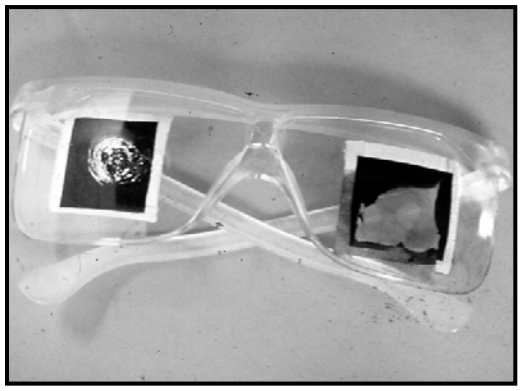
## Monochromaticity



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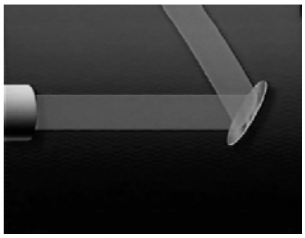
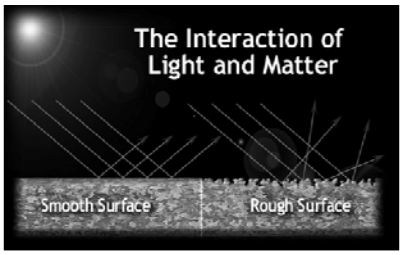
# Reflection



**Specular**




**Diffuse**

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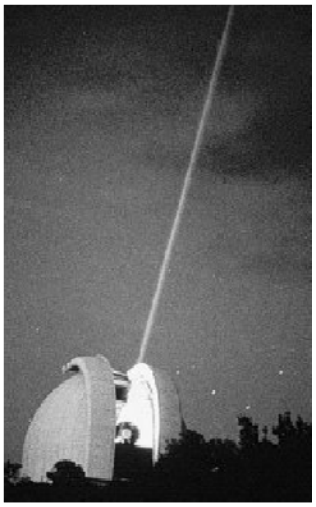
# Directionality

- The laser beam can pose a hazard at a considerable distance
- Unlike ionizing radiation, lasers radiation is only hazardous when it is on and when you have line-of-sight to the beam



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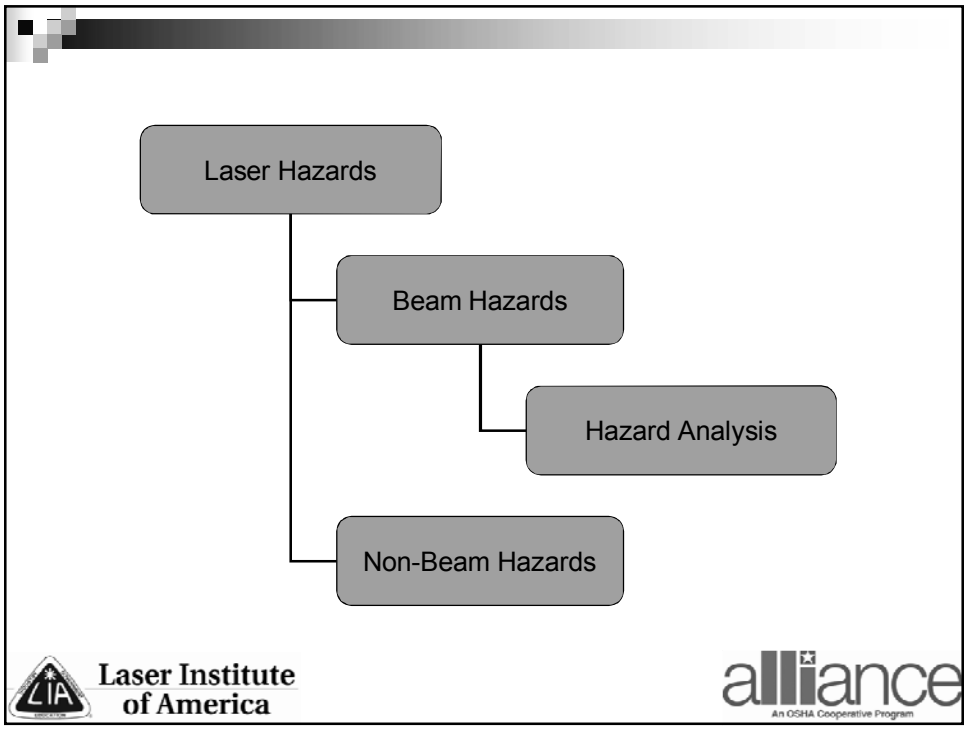
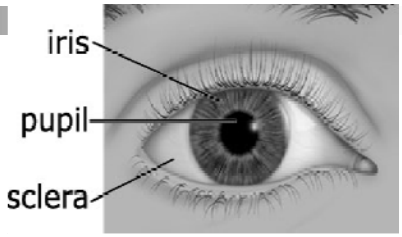
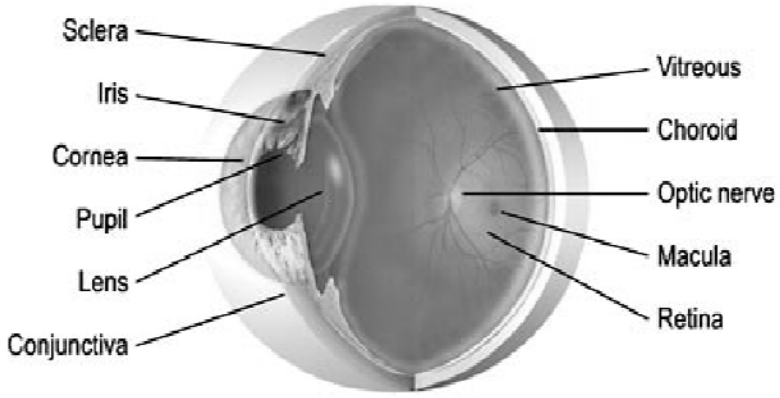
# What are the Laser Hazards?

## Section 5



## Eye Anatomy

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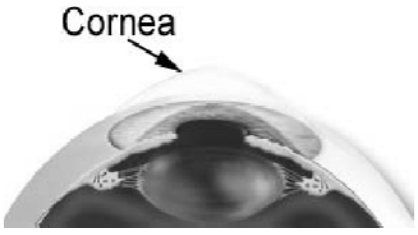
## The Cornea

- The **cornea** is the transparent front part of the eye that covers the iris, pupil, and anterior chamber

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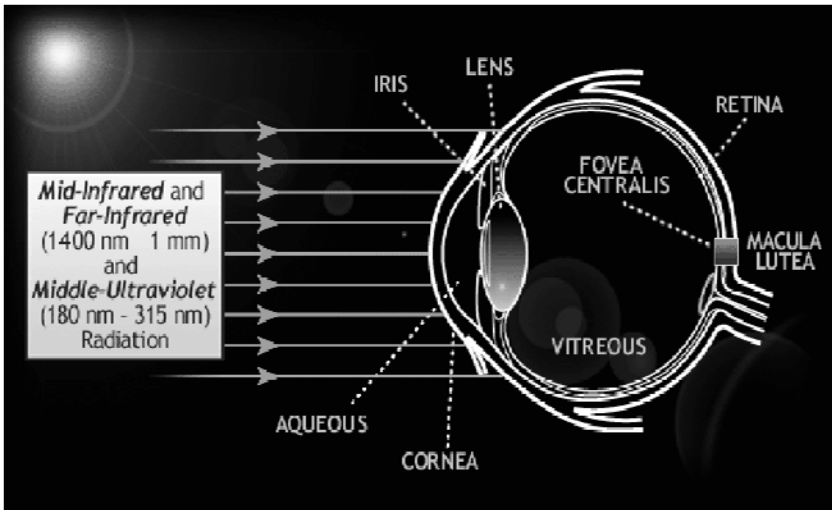
## Ocular Absorption Site vs. Wavelength

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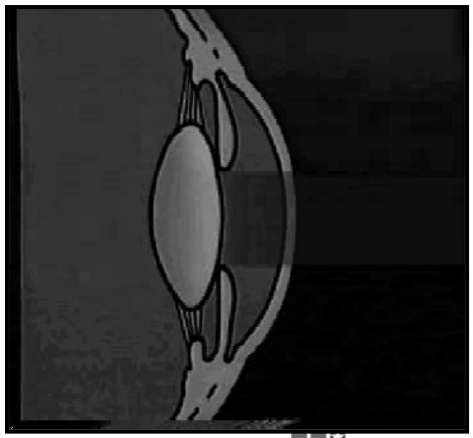
## Corneal Injury

*Photokeratitis and Corneal Thermal Burns*

- Welder's Flash or Snow Blindness
- Burns due to heat



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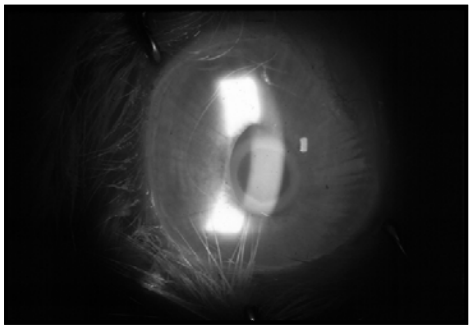
# Corneal Injury



- Superficial (Threshold) Injury
- Deep Burns.

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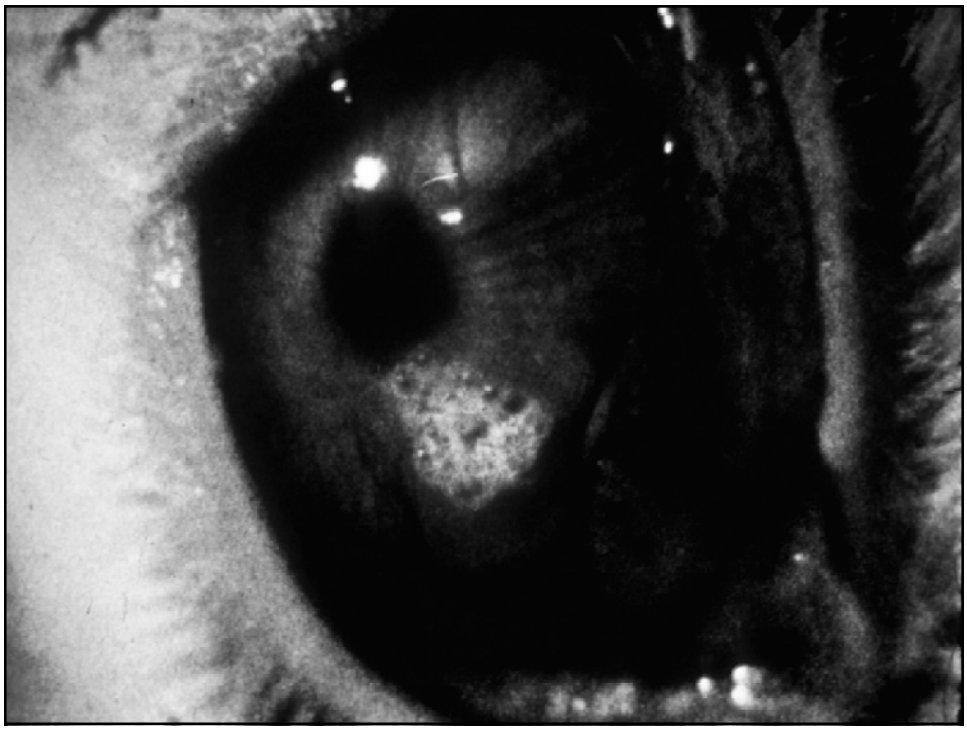
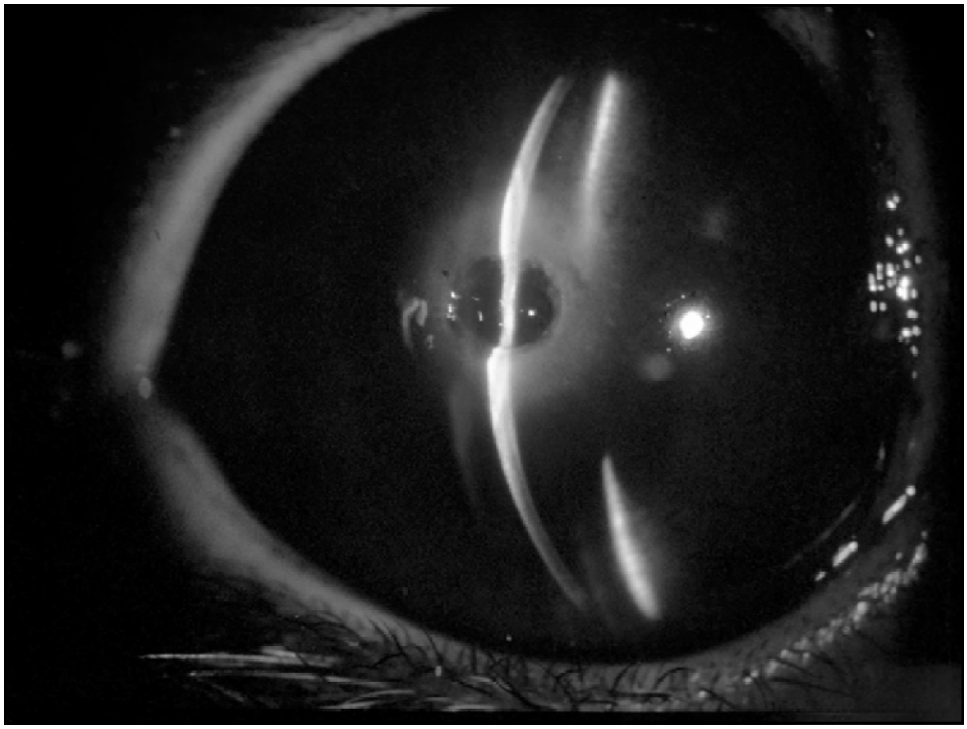
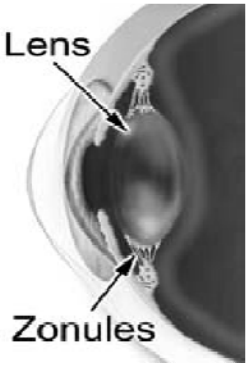




## The Lens

- Lens - Provides accommodation, the ability to focus on near objects

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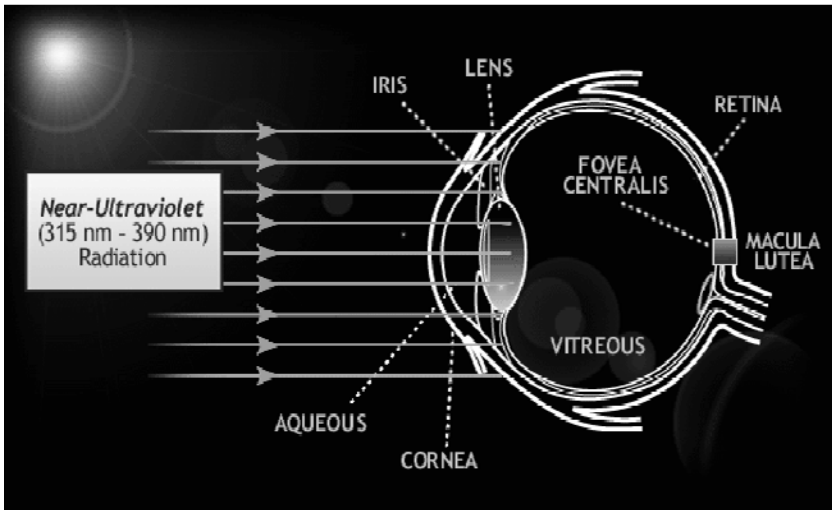
## Ocular Absorption Site vs. Wavelength

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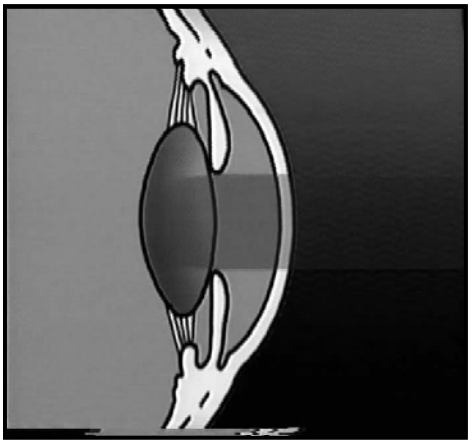
## Cataract - clouding of the lens

- Exposure to Ultraviolet radiation (UV-B).
- Infrared (Heat)



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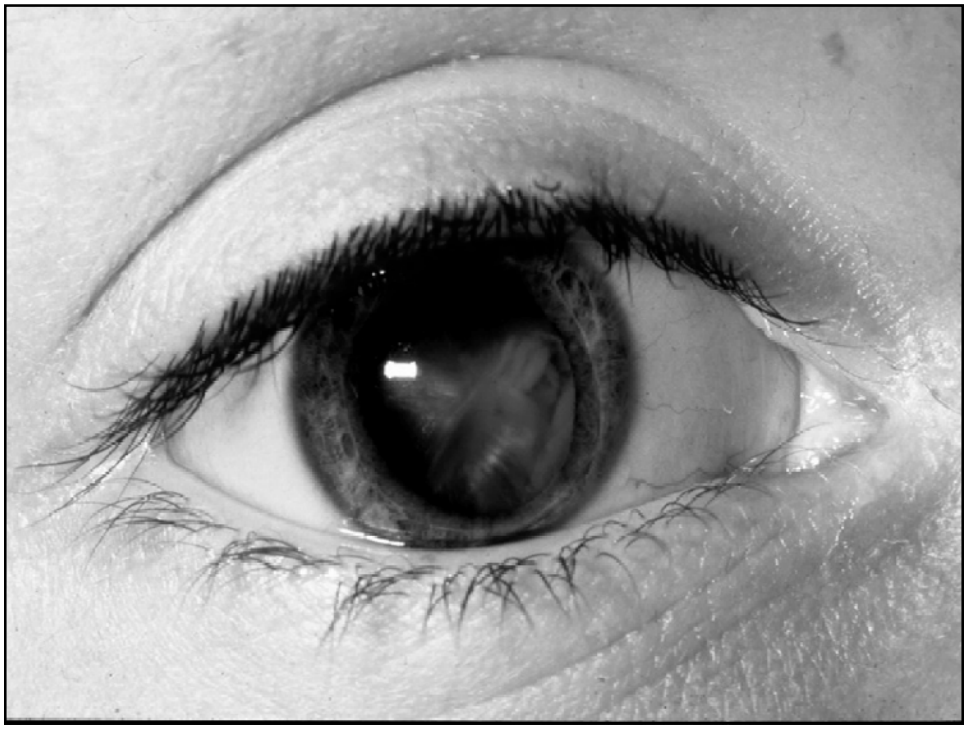
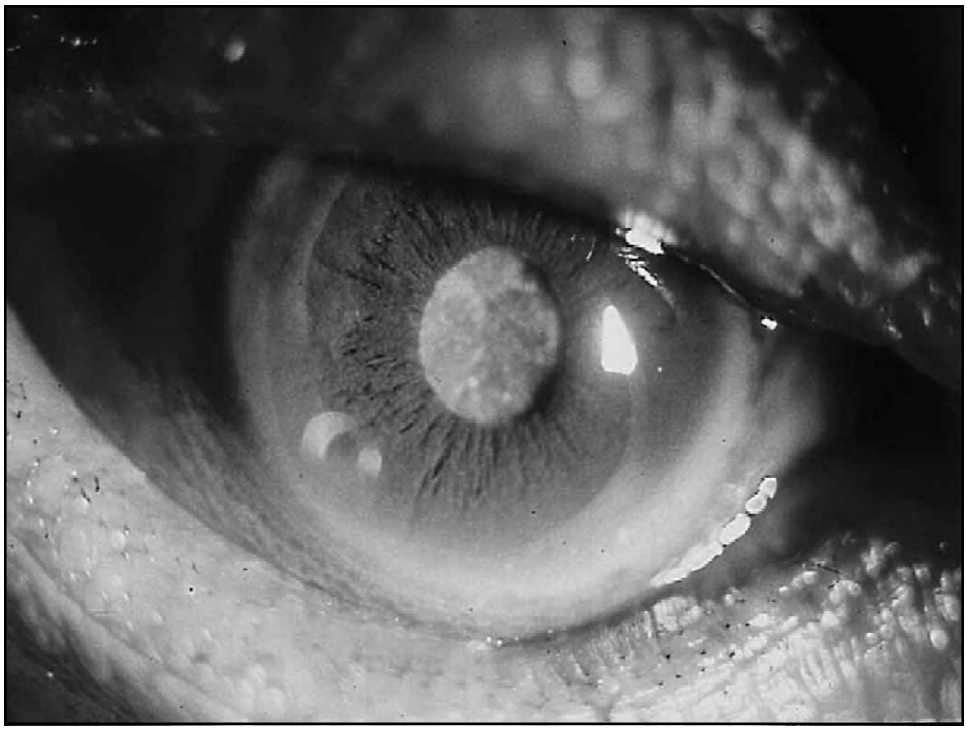


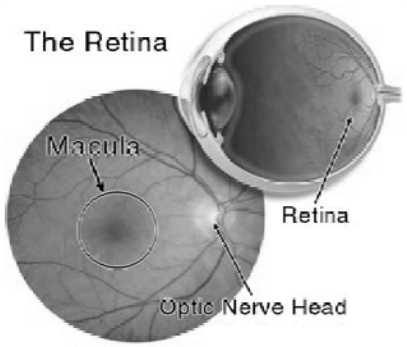


# The Retina

Macula Lutea
- Highest visual acuity

Fovea Centralis
- Center of macula.
- Highest concentration of cones.

Peripheral Retina
- High concentration of rods

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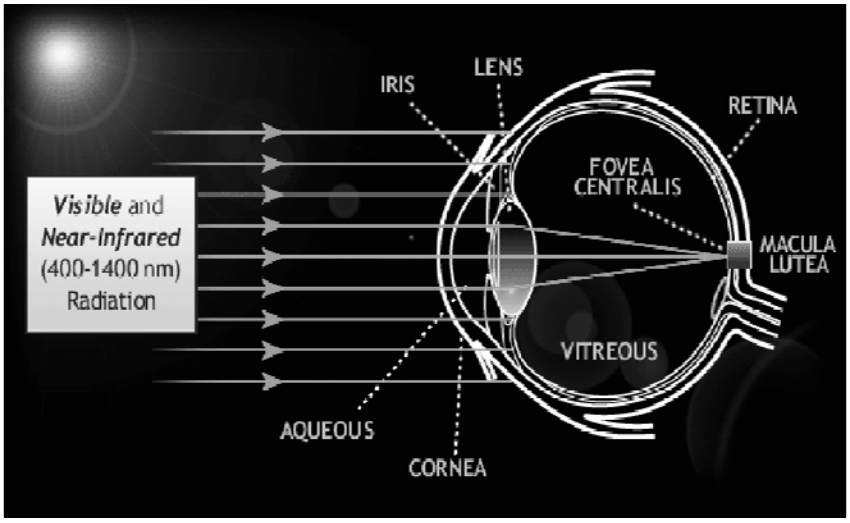
# Ocular Absorption Site vs. Wavelength

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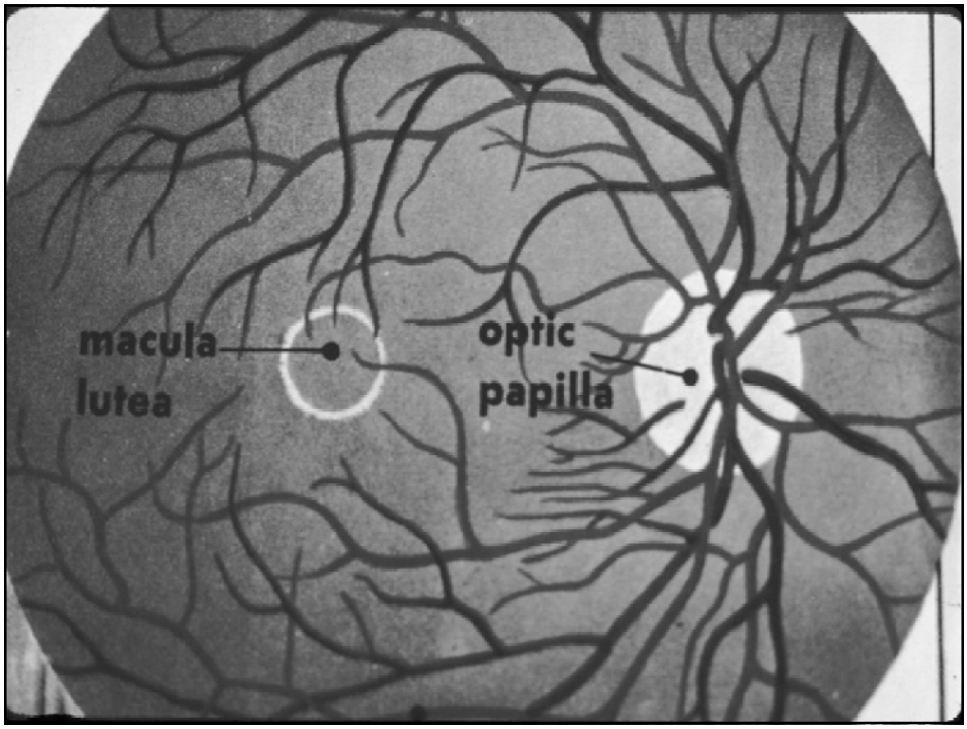
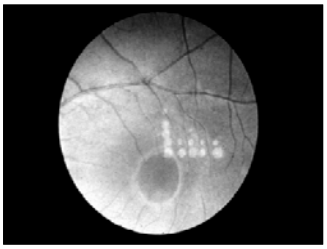
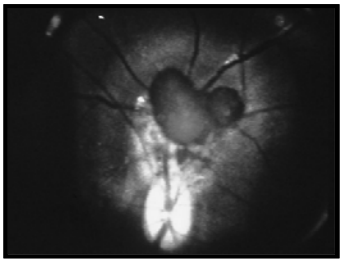



# Retinal Injury

Retinal Thermal Burns or “Chorioretinal burns”,



Retinal hemorrhage



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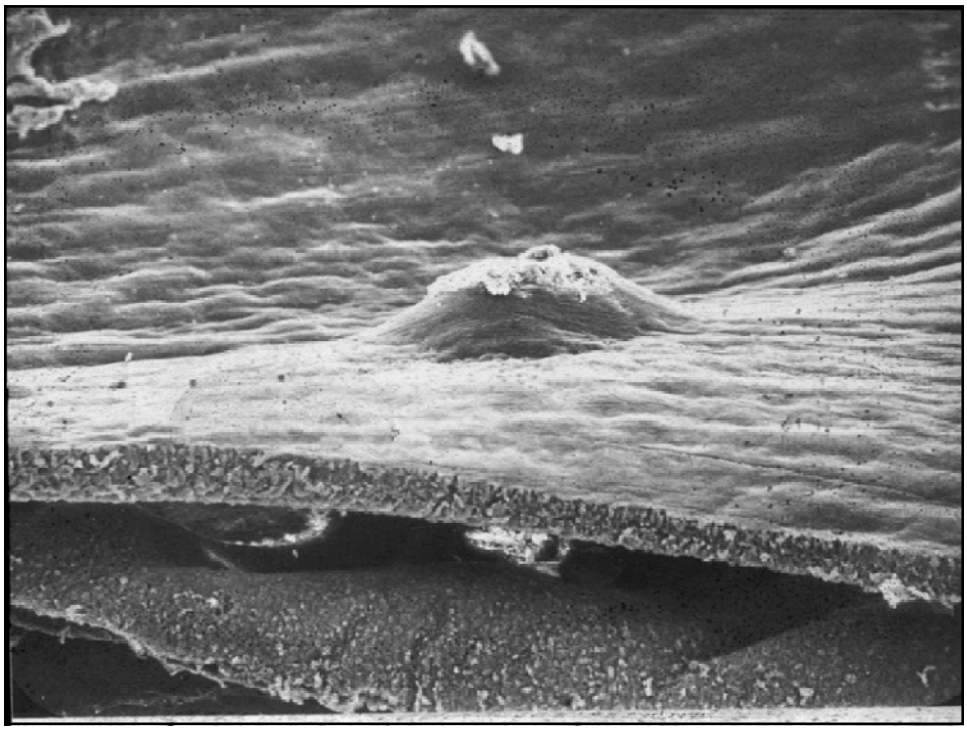
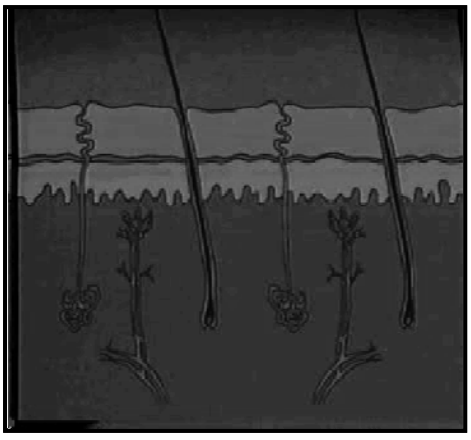


## Skin Hazards

- Different wavelengths are absorbed by different structures in the skin and at different depths



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# Skin Injury

- Thermal Skin Burns
  - Rare but most common from $CO_2$, laser exposure.
- Ultraviolet "Sunburn"
  - Erythema (reddening) from UV-B and UV-C radiant energy.

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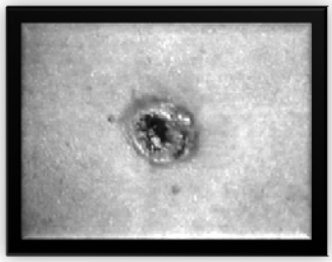
# Skin Injury

- $CO_2$ laser
- Most notable injuries
  - Holes in skin
  - 3rd degree burns
- Nd:YAG laser skin burns are more penetrating, and take longer to heal



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Is there a safe limit that one could be exposed to without getting hurt?

Section 6

## Maximum Permissible Exposure (MPE)

- Definition
  - Maximum level of exposure to laser radiation without hazardous effect or adverse biological changes in the eye or skin


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# Maximum Permissible Exposure (MPE)

- Used to determine
  - Nominal hazard zone (NHZ)
  - Optical density (OD)
  - Accessible Emission Limit (AEL)

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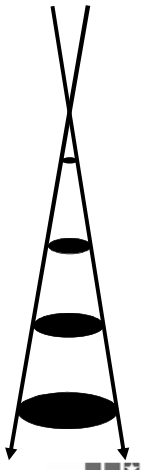
# The Nominal Hazard Zone, NHZ

- The NHZ is the space within which the level of direct, reflected or scattered laser light exceeds the MPE level for the laser.



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## The Nominal Hazard Zone, NHZ:
## Nominal Hazard Zones (NHZ) for Various Lasers

| | | Nominal hazard distance (m) | | |
|---|---|---|---|---|
| **Laser Type** | **Exposure Duration** | **Direct** | **Lens-on Laser** | **Diffuse** |
| Nd:YAG | 10 s | 790 | 6.4 | 0.8 |
| $CO_2$ | 10 s | 399 | 5.3 | 0.4 |
| Argon | 0.25 s | 505 | 33.6 | 0.25 |

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# How do we protect ourselves from Laser Radiation?

## Section 7

# Enclose the Process

- Plastics most often used include:
  - Poly(methyl methacrylate) such as Plexiglass
  - Polycarbonate such as Lexan
- Plexiglass chamber at right is for argon laser (488 nm = blue light)


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# Enclose the Process: Polycarbonate for $CO_2$ Lasers

- PC windows in semi-enclosure for plate cutting laser
- Semi-enclosure: open on top

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## Enclose the Process: Polycarbonate for $CO_2$ Laser Conveyor Enclosures

- Turn-key products are often Class IV due to CDRH definition of "human access" and conveyor openings
- LSO should determine if NHZ extends out conveyor entrance/exit

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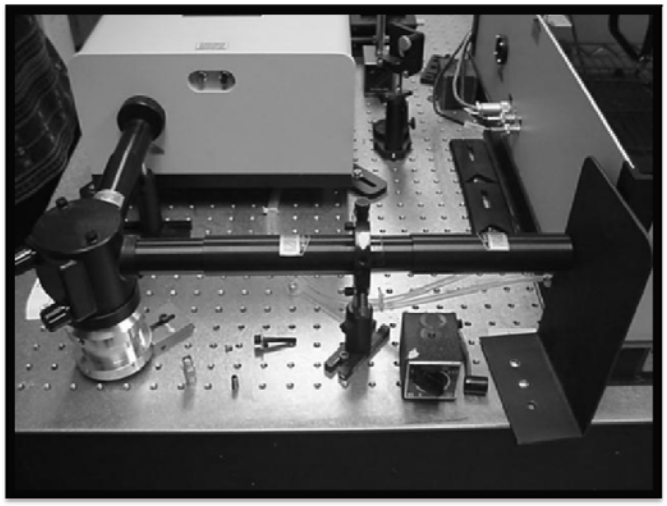
## Enclose Beam Path



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## Enclose and View Remotely


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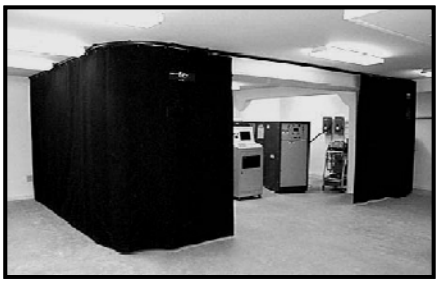
## Laser Barriers and Curtains

- Can be used to limit beam path if it carries beyond the Nominal Hazard Zone



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# Questions to Ask

- Question 7: Is laser eyewear required and used?
- Rationale: This is an indication of awareness and training. Ask to see eyewear and check that it is properly marked with OD and wavelength. Also check to see if it is properly stored. As with any form of PPE it needs to be in working condition.

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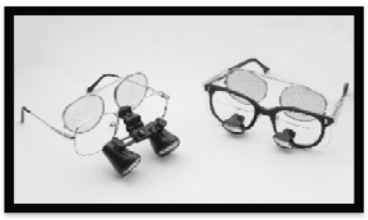
# Laser Safety Eye Protection

- Glass
  - scratch resistant
  - stability against bleaching
  - ease for prescription lenses
  - higher optical quality
  - good visual transmittance
- Plastic
  - low weight
  - break resistant
  - Less expensive



Courtesy Innovative Optics

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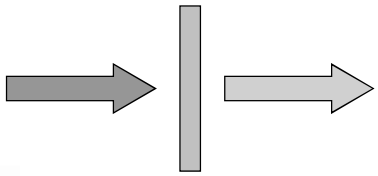
# Optical Density D(λ)

- OD is the base 10 logarithm of the attenuation factor associated with the filtration medium
- Attenuation factor is the ratio of the laser beam irradiance striking the filter divided by the irradiance transmitted by the filter



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# Optical Density OD

| OD | Attenuation | Transmission |
|---|---|---|
| 1 | 10 | 0.1 |
| 2 | 100 | 0.01 |
| 3 | 1000 | 0.001 |
| 4 | 10,000 | 0.0001 |
| 5 | 100,000 | 0.00001 |
| 6 | 1,000,000 | 0.000001 |

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# Optical Density (OD)


- Eyewear must be marked with OD as a function of wavelength
- Laser eyewear is not for intended direct viewing of the beam
- Some manufacturers mark eyewear “DVO” for “diffuse viewing only”

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# What about the Non-beam Hazards?

## Section 8

## Non-Beam Hazards

- Are a class of hazards that do not result from direct human exposure to a laser beam

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## Non-Beam Hazards & Z136.1-2007, Section 7

- "Non-Beam Hazards"section provides guidance on:
  - Electrical hazards
  - Laser generated airborne contaminants
  - Collateral and plasma radiation
  - Fire hazards Explosion hazards
  - Compressed gases
  - Laser dyes
  - Robotics-associated mechanical hazards
  - Noise
  - Waste disposal
  - Continuing spaces
  - Ergonomics

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# Electrical Accidents

- Electrocution: 5th leading cause of work related injury/death in U.S.
- Electrocution: one cause of laser-related death
- 2nd most often reported cause of laser accidents

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# Capacitor Exposure

- Potential for:
  - Accumulation of residual charge after equipment is deenergized
  - Heating and explosion with high current flow
  - Explosion from capacitor's internal failure
  - Arcing at contact point for internal failure

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# Arc Burn

4.3 ELECTRIC ARC/BLAST

Most people are very aware of the dangers of electrocution associated with electrical work. Fewer people, however, recognize the extreme hazards associated with the electric arc/blast. Electrical burns can be received from an electric arc due to a short circuit or ground fault. The heat generated by an electric arc can reach temperatures from 15,000 °F. up to 35,000 °F. which is a little over four (4) times the temperature of the surface of the sun. Only thermonuclear reactions and the laser, which generates temperatures up to 100,000 °F. can develop hotter temperatures here on earth.

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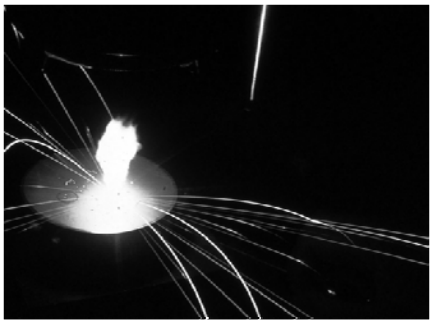
# Laser Generated Air Contaminants (LGAC) Sec 7.3

- Generated when class 3B or 4 laser beams interact with matter
- LGAC depends upon target material, cover gas and beam irradiance
- Difficult to predict what LGAC is released into air



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# Laser Generated Air Contaminants (LGAC)

- When target irradiance reaches $10^7$ W·cm$^{-2}$
  - Target materials may liberate carcinogenic, toxic and noxious airborne contaminants (table F1(a), appendix F)
- LGAC released may be gaseous or particulate (see table F1(b))
- LSOs responsibility to ensure that any IH issue be addressed and he/she may consult with Industrial Hygienist

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# Laser Generated Air Contaminants (LGAC) Aerosols

- Types: dust, mist, fume, smoke, fog, smog
- Interests: composition, size, distribution, concentration

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## Plasma Radiation example

- IR beam interacts with stainless steel
- Small spot of light is visible beneath nozzle
- Bright and rich in blue wavelengths

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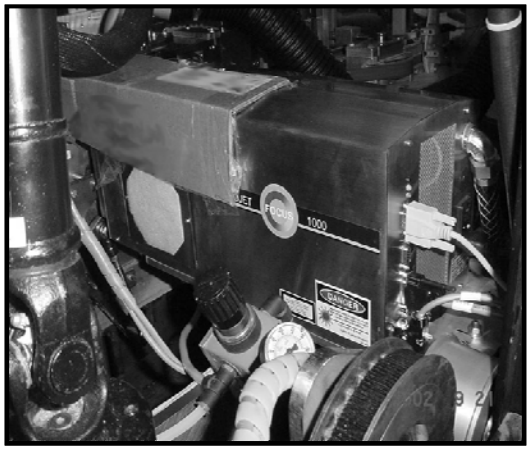
## Fire Hazards – Combustible Materials

- Enclosure materials
- Construction materials
- Target materials
- Laser Gases
- Solvent vapors
- LGAC



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## Compressed Gas

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## How do we protect ourselves from non-beam hazards?

Section 9

# Electrical Hazards Control - Capacitors

- Restrict access until capacitors are discharged, shorted, and grounded
- Consider capacitor cases “Hot”
- Store capacitors shorted
- Verify automatic discharge devices
- Conduct manual shorting - don’t trust auto-discharge

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# Electrical Hazards Controls - PPE

- Wear safety glasses
- Use insulating (rubber) gloves & arm covers as applicable
- Wear “flash suit” for high-voltage work
  - NFPA 70E Standard
  - Tested according to ASTM F-1506

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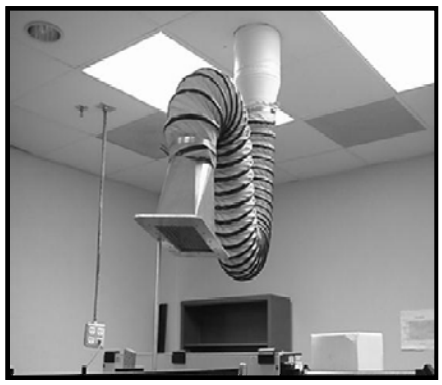
## Control Measure:
## Laser Generated Air Contaminants (LGAC)

- Control measures
  - Exhaust ventilation
    - Hoods, ducts, air cleaners, and fans
    - Comply with latest version of *Industrial Ventilation & Fundamentals Governing the Design & Operation of Local Exhaust Systems* (ANSI Z9.2)
  - Respiratory protection
    - Used to control brief exposure or as interim control until engineering control are put in place
    - Compliance with OSHA (29CFR 1910.134)



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## Control Measure:
## Laser Generated Air Contaminants (LGAC)

Process Isolation

- Surround process with barrier, remote control devices, robotic manipulators
- Especially when laser welding or cutting of materials such as plastics, biological material, composite substrates


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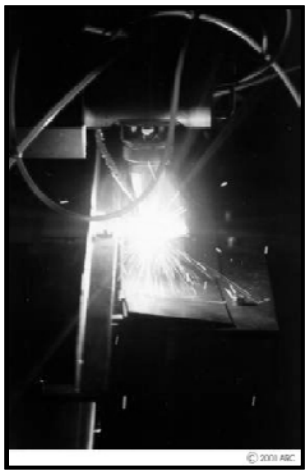
## Control Measure: Plasma Emission (180 to 550 nm)

- Blue-green spectral region
  - Eyewear that is a minimum OD of 2.0 to 3.0
  - Or welding shade of 6 (ANSI Z87.1-2003)
- Greater ODs may be required for higher powered cutting or welding systems
- Plasma emission ODs do not replace OD emissions for lasers



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## Control Measure: Fire Hazards

- Remove flammable substances and compounds from the laser area
- Enclose area with laser flame retardant barriers
- Follow NFPA Code #115

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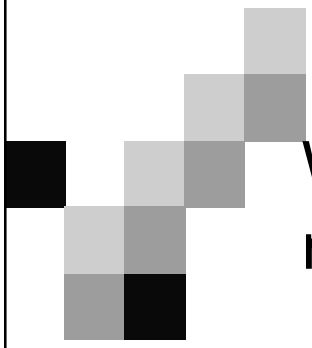

# What other control measures are there?

Section 10

## Laser Controlled Areas

- Class 3B laser controlled area
- Class 4 laser controlled area
- Temporary laser controlled area

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## Class 3B Laser Controlled Area ANSI Z136.1-2007 Sec. 4.3.10.1

- Operated by authorized & trained personnel
- Posted with warning sign
- Operated in manner beam path well defined
- Limit beam path if extends beyond NHZ
- 8 “should” points - p. 33 in ANSI Z136.1-2007

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## ANSI Z136.1 “Should” Points

- Be under the direct supervision on an individual knowledgeable in laser safety

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## ANSI Z136.1 “Should” Points

- Be located so that access to the area by spectators is limited and requires approval

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## ANSI Z136.1 “Should” Points

- Have any potentially hazardous beam terminated in a beamstop of an appropriate material

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# ANSI Z136.1 “Should” Points

- Have only diffusely reflecting materials in or near the beam path, where feasible


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# ANSI Z136.1 “Should” Points

- Provide personnel within the laser controlled area with the appropriate eye protection

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# ANSI Z136.1 “Should” Points

- Have the laser secured such that the exposed beam path is above or below eye level


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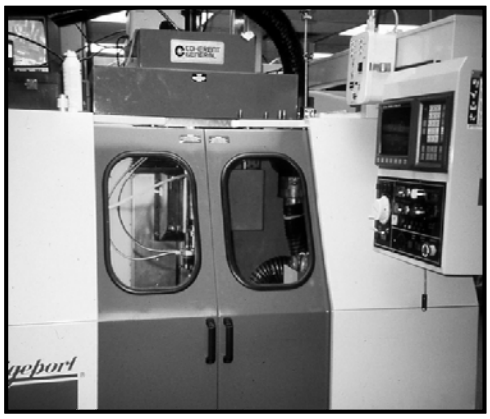
# ANSI Z136.1 “Should” Points

- Have all windows, doorways, open portals, etc. from an indoor facility be either covered or restricted…



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## ANSI Z136.1 “Should” Points

- Require storage or disabling of the laser or laser system when not in use to prevent unauthorized use

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## Questions to Ask

- Question 8: Are access control measures in place such as interlocks or visual indicators?
- Rationale: Only authorized personnel should have access to laser operation areas.

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# Class 4 Laser Controlled Area

- All “shall” and “should” requirements of Class 3B lasers
- Clearly marked “panic button” to interrupt laser beam
- Entryway controls:
  - non-defeatable
  - defeatable
  - procedural


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# Entryway Controls

- Non-defeatable
  - hardware is used to deactivate laser, or reduce levels of MPE
- Defeatable
  - allows override of interlocks
  - controls deactivate laser or activate beam controls upon entry by individuals
- Procedural
  - individuals are trained and given PPE
  - laser radiation attenuated at entry
  - visible or audible signal that laser is operating

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# Defeatable Entryway Controls

- Key-controlled momentary by-pass switch
- Lighted sign over door; ANSI-type sign on door
- Absorbing viewing panel in door for lone-worker policy


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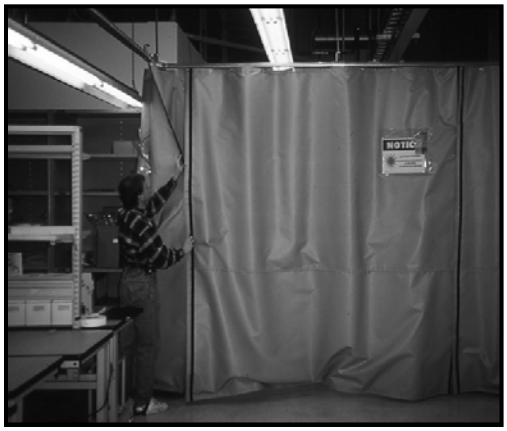
# Temporary Laser Controlled Area

- Laser curtains may be used to isolate a laser being serviced while other near-by lasers continue normal operation
- Generally applicable to "service" conditions
- Note, sign pocket holding "Notice" sign



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## Entryway Controls: Lighted Sign



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## Interlock Switches


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## Questions to Ask

- Question 9: Ask to see laser warning signs. Are they accurate and ANSI compliant? Are they posted correctly?
- Rationale: Signage is part of hazard communication. They need to be accurate and ANSI compliant. A "Laser in Use" sign is not sufficient information.

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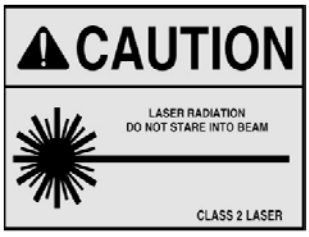
## Signs and Area Posting

- Signal Words
  - Caution
  - Danger
  - Notice
- Caution Signs
  - Class 2
  - Class 3R, low irradiance
- Danger Signs
  - Class 3R, high irradiance
  - Classes 3B/4
- Posting required for Classes 3B and 4





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## Sample Warning Sign for Temporary Controlled Area

Z136.1-2007 requires the use of a warning sign for a temporary laser controlled area. Signal word: “Notice”


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## Who gets injured?

## Section 11

# Laser Accidents and Incidents

- Laser class: IV > IIIB >> IIIR
- Beam scenarios
  - eye exposure: temporary/permanent vision loss
  - skin exposure: burns or photochemical effects
- Non-beam scenarios
  - shock/electrocution
  - exposure to chemical agents
  - ignition of flammables/combustibles

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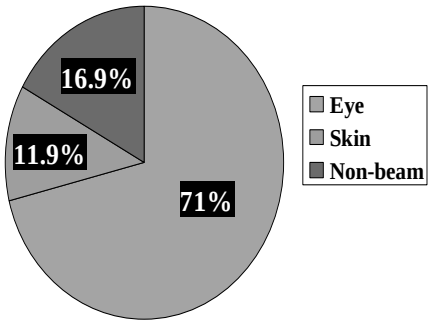
# Laser Accident & Incidents: Overview

- Top 5 lasers: Nd:YAG, Ar, $CO_2$, dye, diode
- Breakdown of incidents
  - 71% - eye injury
  - 11.9% - skin injury
  - 16.9% - non-beam incident




Data from Rockwell, RJ, ILSC 99 proceedings, LIA

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# Personnel Exposure Summary

Accident Data Summary: Division of 395 events: 1964-1998

| | |
|---|---|
| Technicians Exposed (81): | 20.5% |
| Scientists Exposed (78): | 19.8% |
| Students Exposed (46): | 11.6% |
| Patients Exposed (40): | 10.1% |
| Plant Workers Exposed (35): | 8.9% |
| Dr.s & Nurses Exposed (26): | 6.6% |
| Pilots & Military Exposed (26): | 6.6% |
| Spectators Exposed (25): | 6.3% |
| Laser Show Operators Exposed (11): | 2.8% |
| Equipment only damaged (10): | 2.5% |
| Field Service Exposed (10): | 2.5% |
| Office Staff (uninvolved) (7): | 1.8% |

Data from Rockwell, RJ, ILSC 99 Proceedings, LIA

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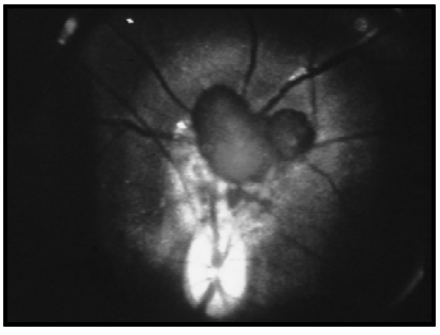
# Laser Incidents: Eye Injury

- >70% of all incidents
- 82.3% of severe eye injury caused by Nd:YAG, Ar, dye, ruby, dbl-Nd:YAG and Ti:Sapphire
- Laser light shows have resulted in transient effects (e.g., flash blindness) to airplane pilots



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# Laser Incidents: Eyewear Concerns

- Not using eyewear (may have been available)
- Eyewear failure
- Improper eyewear
- Improper fit

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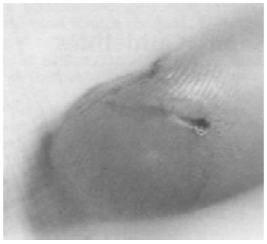
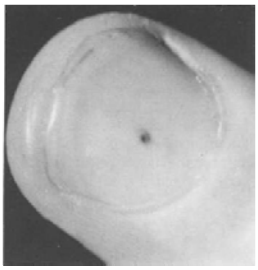
# Skin Injury

- $CO_2$ laser – most often implicated
- Most notable injuries
  - Holes through fingers
  - 3rd degree burns
- In general, non-debilitating





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## Laser Accidents: Fire

- $CO_2$ > Nd:YAG, dye
- Beam: $CO_2$ & Nd:YAG
- Clothing: e.g., ties
- Solvents: dye

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## Laser Accidents: Death

- Blood loss (9)
- Embolism (7)
- Electrocution (5)
- Endotracheal tube fires (3)
- Skin loss (1)

From: Johnson & Wartick, ILSC 2003 Conf. Proc. Prog.

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# Most Hazardous Act


- Act of adjusting the optics in the beam path in relation to each other so the beam will propagate in some pre-determined manner; may be internal to laser or external.

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# Laser Accidents: Alignment

- Estimates
  - ~1/3 of all (known) accidents
  - ~60-70% of all (known) laboratory accidents
- Common scenario: unanticipated reflection from an optic while not wearing protective eyewear

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## Questions to Ask

- Question 10: Do you have a procedure in place for responding to laser accidents?
- Rationale: As with any type of accident there needs to be a response plan.

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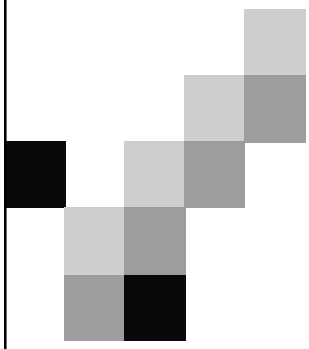

# Other Consensus Standards & Regulations

Section 12

# Laser Safety Standards: USA

- ANSI Z136.1 (2007) *for Safe Use of Lasers*
- Z136.2 (1997) *for Safe Use of Optical Fiber Communication Systems Utilizing Laser Diode and LED Sources*
  - DOES NOT EXIST-Was administratively withdrawn
- ANSI Z136.3 (2011) *for Safe Use of Lasers in Health Care*

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# Laser Safety Standards: USA

- ANSI Z136.4 (2010) *Recommended Practice for Laser Safety Measurements for Hazard Evaluation*
- ANSI Z136.5 (2009) *Safe Use Of Lasers In Educational Institutions*
- ANSI Z136.6 (2005) *Safe Use Of Lasers Outdoors*
- ANSI Z136.7 (2008) *for Testing and Labeling of Laser Protective Equipment*
- ANSI Z136.8 (2012) *for Safe Use of Lasers in Research, Development, or Testing*

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## Questions to Ask

- Question 11: Are all the lasers in use certified?
- Rationale: Requirement of CDRH.

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## Laser Regulations: FDA

- 21 CFR Subchapter J – Federal Laser Product Performance Standard (FLPPS)
  - Applies to laser product manufacturers and those modifying laser products
    - Selling in US
    - Legally binding
  - Requires certification of laser products, and 1st step is classification
- http://www.fda.gov/Radiation-EmittingProducts/default.htm

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## CDRH Federal Laser Product Performance Standard

- Basic Principle: Radiation must be eliminated or safely contained except where and when access is necessary to provide function.

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## CDRH Federal Laser Product Performance Standard

- FDA does not consider a product to have been “manufactured” if it is constructed on a one time basis, by a particular company, for use in its manufacturing process at the place where constructed.

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# CDRH Federal Laser Product Performance Standard

- FDA will not consider multiple products to have been “manufactured” provided they
  - are not shipped in interstate commerce
  - are used solely at the place where constructed
  - are used by the same employees who constructed them
  - are not made on a recurring basis

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# Laser and Laser System Engineering Requirements


- All lasers must have:
  - Protective Housing
    - Safety interlocked to prevent access to laser radiation
  - Key Control
  - Laser Emission Indicator
  - Manual Reset

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# Labeling Requirements of the CDRH Standard

- All lasers must have:
  - Certification label
  - Identification label
  - Name and address of manufacturer
  - Place, month, and year of manufacture
  - Hazard classification
  - Radiation output info and warning logotype
  - Aperture label


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# Acts Prohibited by the CDRH Standard

- Sale of noncompliant products
- Failure to notify
- Failure to establish and maintain records
- Failure to certify; false certification

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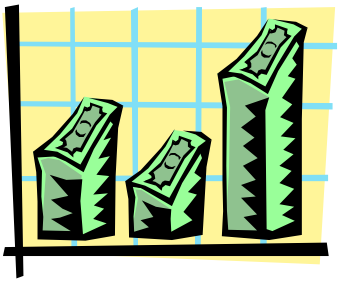
# Penalties Specified by the CDRH Standard

- $1000 per violation
- $330,000 per series of violations
- Can apply to any person - firm or individual



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# International Laser Safety Standards

- International Electrotechnical Commission (IEC)
  - IEC 60825-1, for the Safety of Laser Products
- CDRH Laser Notice No. 50 permits manufacturers to classify their products in accordance with IEC 60825-1

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# General Duty Clause

- **Michigan 2005:** "The employer did not furnish employment and a place of employment which were free from recognized hazards that were causing or likely to cause death or serious physical harm to employees in that employees were exposed to the hazards of infrared non-ionizing radiation capable of causing severe burns of the eyes and skin. Specifically, class IV, metal cutting lasers (1800 watts, carbon dioxide, wavelength 10.6 μm)…"
  - "Facility using high powered CO2 laser for cutting metal products. Employees were using standard safety glasses and there was no guarding at and near where the laser was cutting metal. The company did not provide a laser safety program or have a laser safety officer at the time of investigation."

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# General Duty Clause

- Citation specifies:
  - No written SOPs to ensure that operators and nearby employees area not excessively exposed to non-ionizing radiation.
  - No LSO, education and training, control measures, medical surveillance program.
  - $500 monetary penalty, 30 days to fix

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# General Duty Clause

- Recommendation: "One feasible method of compliance is to conform to the requirements of the American National Standards Institute Publication, ANSI Z136.1-2000."


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# OSHA Web Resources

- Safety and Health Topics
  - Laser Hazards
    - http://www.osha.gov/SLTC/laserhazards/index.html
- Laser Institute of America
  - http://www.lia.org/subscriptions/news/releases/Alliance/
  - http://www.LIA.org

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# Laser Regulations: Various States & Municipalities

- Comprehensive regulations: Alaska, Arizona, Arkansas, Florida, Illinois, Georgia, Massachusetts, New York, Texas, Washington
- Laser pointer regulations (pending & adopted): Arkansas, California, Hawaii, Kansas, Illinois, Maine, Maryland, Massachusetts, Michigan, New Jersey, New York, North Carolina, Rhode Island, Tennessee, Texas, Virginia, and Washington
- Local ordinances restrict purchase of laser pointers by minors and/or restrict use

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# Other Questions Inspectors Should Ask?

## Section 13

## Questions to Ask

- Question 12: Have employees been given training? Ask to see the records.
- Rationale: Requirement of ANSI Z136.1.

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## Questions to Ask

- Question 13: If running more than one shift, how are laser safety concerns dealt with?
- Rationale: It is important that second and third shift employees have the same training as first shift.

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## Thank You!

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