OSC 12
Ohio Safety Congress & Expo

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333 The Basics of Laser Safety in the Workplace

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Wednesday, March 28, 11 a.m. to Noon

Ohio | Bureau of Workers' Compensation

Laser Safety in a Whole New Light
Rockwell Laser Industries

The Basics of Laser Safety in the Workplace

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Outline

- **Laser Concepts**
- **Skin and Eye Biological Effects & Non-Beam Hazards**
- **Laser Accidents**
- **Laser Classification**
- **Laser Safety Standards**
  - **Product Standards**
  - **User Standard**
- **Laser Hazard Analysis**
- **Laser Control Measures**

Laser Concepts

Laser

***L*ight**
***A*mplification by**
***S*timulated**
***E*mission of**
***R*adiation**

The acronym **LASER** stands for **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation. It is important to realize that the energy emitted by a laser is electromagnetic energy with a wavelength that lies in or near the visible portion of the spectrum.

While many lasers emit visible beams, there are also many lasers that emit invisible beams in the ultraviolet or the infrared parts of the spectrum.

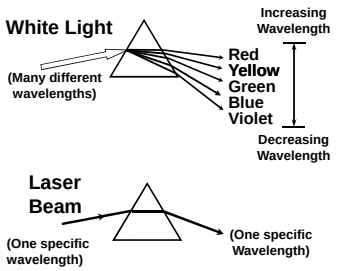
Characteristics of Laser Light

Monochromatic
Directional
Coherent

The term *Monochromatic* means that it consists of one single color or wavelength. Even though some lasers can generate more than one wavelength, the light is extremely "pure" and consists of a very narrow spectral range. Secondly, a laser beam is *Directional* which means that the beam is very well collimated and travels over long distances with very little spread. *Coherence* means that all the waves of light energy emitted by a laser are in phase with each other.

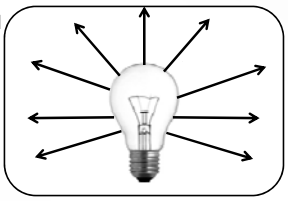
The combination of these three properties makes laser light focus to a spot size that is 1/100th the size of focused ordinary light.

White v. Monochromatic Light



Characteristics of Laser Light

- Directional

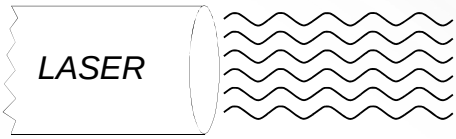


"Ordinary" Light Source

Incoherent Source

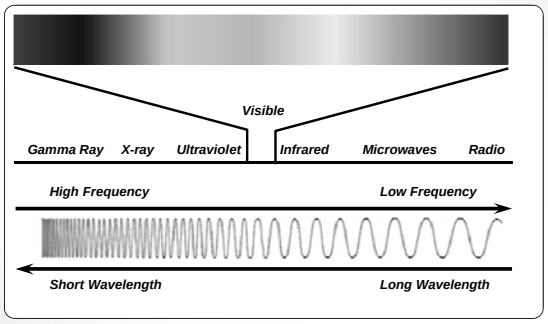
Characteristics of Laser Light:

- Coherent



The US Army Marching Band

The Electromagnetic Spectrum



Types of Industrial Lasers

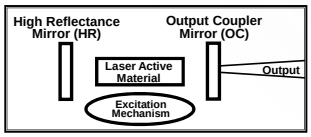
- **Gas** lasers use gas atoms, molecules, or ions in a tube. A mixture of gases is sometimes used. They are excited by electric current passing through the gas.
  (Carbon Dioxide – 10600nm / HeNe – 633nm)
- **Solid State** lasers employ metal ions embedded in a transparent crystal and are excited by an arc lamp, a flashlamp, or another laser.
  (Nd:YAG – 1064nm / Ti:Sapphire – 650 to 1180nm)
- **Diode** lasers use electrons passing across the boundary between two layers of semiconductor material and are excited by an electric current. (GaAs – 850 to 904nm)

Essential Laser Components

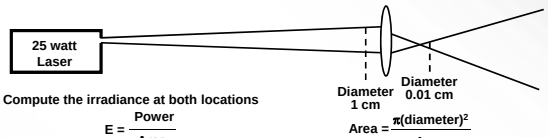
Active Medium
Solid State
Liquid
Gas
Semi-Conductor

Excitation Mechanism
Optical
Electrical
Chemical

Optical Resonator
Highly Reflective (HR) mirror &
Output Coupler (OC) or Partially Reflecting (PR) mirror



Irradiance Analysis



Compute the irradiance at both locations

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

$$\text{Area} = \frac{\pi(\text{diameter})^2}{4}$$

Irradiance at lens entrance

$$E = \frac{25 \text{ watts}}{\pi\,(1\text{cm})^2/4}$$

$$E = 32 \text{ watts/cm}^2$$

Irradiance at focal point

$$E = \frac{25 \text{ watts}}{\pi\,(0.01\text{cm})^2/4}$$

$$E = 320{,}000 \text{ watts/cm}^2$$

The two calculations shown above illustrate the effect that ***focusing of the laser beam*** has on the magnitude of the irradiance. Shown is a 25 watt laser beam with calculations of irradiance at two different locations; one at a point in the direct beam where the beam diameter is 1cm in front of the entrance to the lens, and the other at the focal point of a lens where the spot diameter is 0.01cm. Without increasing the power, the irradiance at the focal point of the lens is ***10,000 times greater*** than at the designated point in front of the lens.

Summary

- **Unique Characteristics**
  - Coherent
  - Directional
  - Monochromatic
- **Three Main Components**
  - Active Medium
  - Excitation Mechanism
  - Optical Resonator (HR & OC Mirrors)
- **Created** in the Active Medium by
  - Stimulated Emission

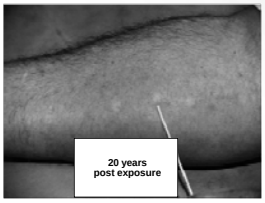
Skin and Eye Biological Effects & Non-Beam Hazards

Laser Tissue Interactions

THERMAL:
- Caused by elevated temperature after absorption of laser energy.
- Occurs at nearly all wavelengths and exposure durations.

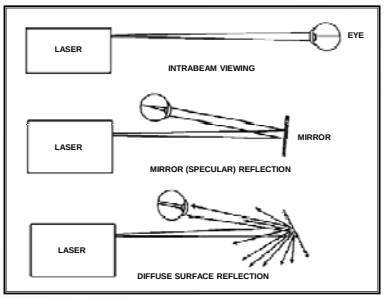
PHOTOCHEMICAL:
- Caused by chemical reactions within body tissue after absorption of laser energy.
- Occurs only with wavelengths less than 0.600 mm.
- Dominant effect for exposure durations greater than 10 seconds.

Long-Term Effects of CO2 Laser Skin Injury

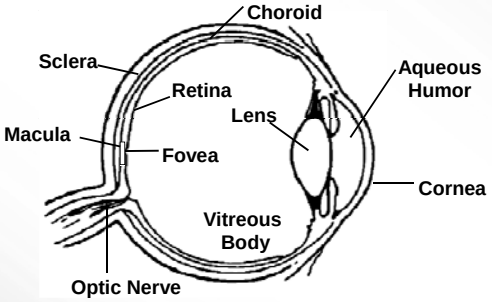


Twenty year evaluation of CO2 laser (5 W/cm2, 1 sec. at 10,600 nm) exposure of human skin. Note: at long term follow up, burn regions display non-descript fibrous scarring. No other symptoms were observed over the twenty year period.

Eye Exposure Geometries



Human Eye



Non-Beam Hazards

- Laser Generated Air Contaminants (LGAC)
- Compressed Gases
- Electrical Hazards
- Explosion and Fire Hazards
- Collateral and Plasma Radiation

Laser Accidents

Commonly Occurring Causes Of Laser-related Incidents

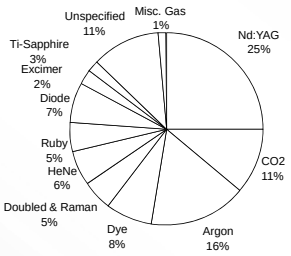
- Unanticipated eye exposure during alignment
- Misaligned optics and upwardly directed beams
- Laser eye protection not used
- Equipment malfunction
- Improper methods of handling high voltage
- Intentional exposure of unprotected personnel

Commonly Occurring Causes Of Laser-related Incidents(2)

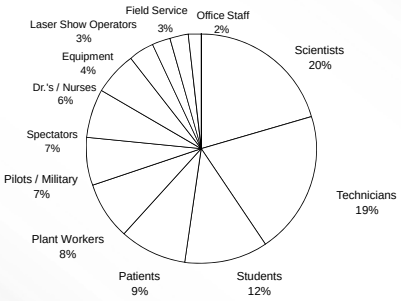
Non-Beam Hazard Incidents:

- Inhalation of laser-generated air contaminants (LGAC)
- Viewing laser-generated plasmas
- Ignition of fires of both facility and personnel nature

Laser Accident Summary
Breakdown of 417 events by laser type



Laser Accident Summary
Breakdown of 417 events by occupation



Laser Classification
ANSI Z136.1 2007

Class 1

Not Known to be Able To Cause Biological Injury

Class 2

Bar Code Scanner

Ocular Hazard for Chronic Viewing Visible Light Only

Laser-Aimed Thermometer

Visible laser for which protection from accidental exposure is provided by the aversion response.

Class 1M

Not Known to be able to Cause Biological Injury Unless Collecting Optics are Used

Class 2M

Ocular Hazard for Chronic Viewing and/or with Optical Instruments Visible Light Only

Class 3R

Ocular Hazard for Chronic Viewing or Viewing with Collecting Optics Visible Light Only (CDRH Only)

Class 3B

Ocular and Skin Hazard for Direct Exposure

Class 4

Ocular and Skin Hazard for Exposure to Both the Direct Beam and Scattered Radiation
Produce Fire Hazards

Laser Safety Standards

Laser Safety Standards

Federal Laser Product Performance Standard (FLPPS)

- **Requires manufacturers to certify laser products**
- **1st step in certification is <u>classification</u>**
- **Product is classified for <u>operation</u>**
- **Manufacturer submits <u>product report</u> to certify that product complies with legal requirements**
- **CDRH assigns an <u>accession number</u> to the product**

State Laser Safety Regulations

- Some have registration requirement for Class 3b and 4 lasers
- Some require LSO and provisions from ANSI Z136.1
  - Controlled areas
  - Inspection of laser eye protection
  - Workplace audits

Overview of ANSI Z136.1

1. APPOINT LASER SAFETY OFFICER
2. ESTABLISH LASER CLASSIFICATION
3. EVALUATE HAZARDS BY DETERMINING
   - MPE
   - NHZ
4. DEFINE CONTROL MEASURES
   - ENGINEERING CONTROLS
     - ENCLOSURES
     - INTERLOCKS
     - WARNING SYSTEMS
   - ADMINISTRATIVE AND PROCEDURAL CONTROLS
     - AUTHORIZED PERSONNEL
     - SOP INCLUDING ALIGNMENT
     - TRAINING
   - PROTECTIVE EQUIPMENT
     - EYEWEAR
     - BARRIERS

Responsibilities of the LSO ANSI Z136.1, Appendix A

1. Establish and maintain the policies and procedures for the laser safety program
2. Classify lasers or confirm hazard class
3. Perform hazard evaluation including NHZ
4. Specify control measures
5. Approve procedures and SOPs
6. Recommend and approve protective equipment
7. Approve area signs and labels

Responsibilities of the LSO ANSI Z136.1, Appendix A

8. Approve installation facilities and modifications
9. Assure adequate training of laser personnel
10. Monitor medical surveillance program
11. Maintain records
12. Perform periodic audits and surveys
13. Investigate accidents
14. Approve laser systems operations

Laser Hazard Analysis

Defining the MPE

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."

. . . "a safe level" . . .

Key Factors in Hazard Evaluation

- **The laser or laser system's capability of injuring personnel or interfering with task performance**
- **The environment in which the laser is used**
- **The personnel who may use or be exposed to laser radiation**

Laser Considerations

- **Wavelength(s)**
- **Exposure time(s)**
- **Temporal operation**
  - CW: Radiant power
  - Pulsed: Energy per pulse & pulse duration; pulse repetition frequency (multiple pulses)
- **Beam diameter**
- **Beam divergence**

Nominal Hazard Zone

The space within which the irradiance or radiant exposure exceeds the appropriate MPE.

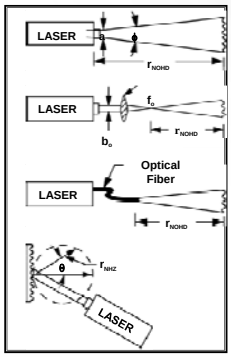
Four Basic NHZ Concepts

Intrabeam:

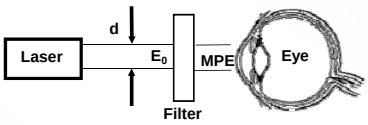
Lens-on-Laser:

Fiber-Optic:

Diffuse Reflection:



Laser Protective Eyewear Optical Density



OD	Attenuation	Transmittance
1	10	0.1
2	100	0.01
3	1000	0.001
4	10,000	0.000 1
5	100,000	0.000 01
6	1,000,000	0.000 001

Laser Control Measures

What Kinds Of Control Measures Are There?

- Engineering
- Administrative & Procedural
- Protective Equipment

Entryway Warning Systems & Activation Warning Signs

Laser Beam Stop

Laser Barrier

Laser Safety Eyewear

Labeling Eyewear

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 3R (or any higher power) laser with optical instruments.
- Never direct the beam toward other people.
- Remove all unnecessary reflective objects from the area near the beam's path. This may include items of jewelry and tools.

Safe Work Practices (2)

- Read the information manual associated with your laser so that you know the laser equipment and hazards associated with its use.
- 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.
- Do not enter a designated Class 3B or Class 4 (posted with a DANGER sign) laser area without approval authorization. Eye protection is required in these areas.
- Position the laser beam so that it is well above or below eye level.
- When not in use, laser should be stored to prevent unauthorized use by untrained personnel.

Thank you.

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