# Understanding Industrial Laser Safety

**Student Materials**
**MTI Level Two Course**
**Consultation Education and Training (CET) Division**
**Michigan Occupational Safety and Health Administration**
**Michigan Department of Labor and Economic Opportunity**
**www.michigan.gov/miosha**
**517-284-7720**

(Revised 02/24)

# Understanding Industrial Laser Safety

**Presented By:**
**Consultation Education and Training (CET) Division**
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MICHIGAN DEPARTMENT OF LABOR & ECONOMIC OPPORTUNITY

MIOSHA Michigan Occupational Safety and Health Administration

1

## Objectives

- Identify basic operation and major uses of lasers
- Identify laser classifications and associated hazards
- Review application of MIOSHA and voluntary standards
- Describe the responsibilities of the Laser Safety Officer (LSO)
- Discuss laser safety training specifics

2

2

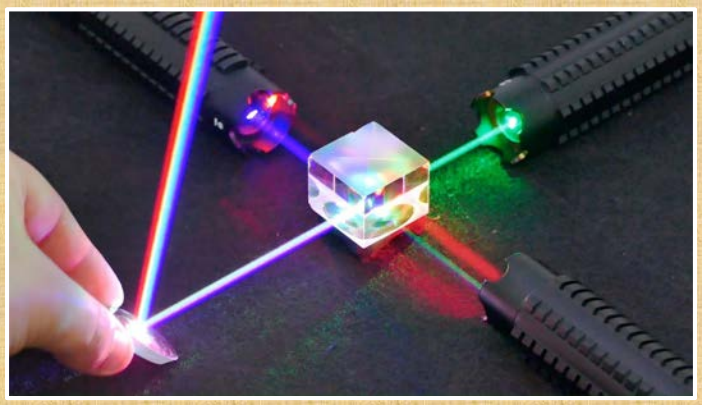
# Basic Operation and Major Uses of Lasers

3

## What is a Laser?

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

Light emitted is non-ionizing electromagnetic radiation.



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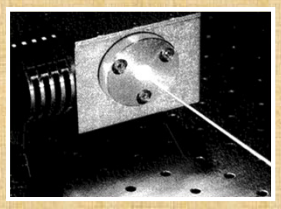
# Laser Radiation Is Light

The sun and light bulbs radiate light in all directions

Laser radiation is a beam of light moving in one direction



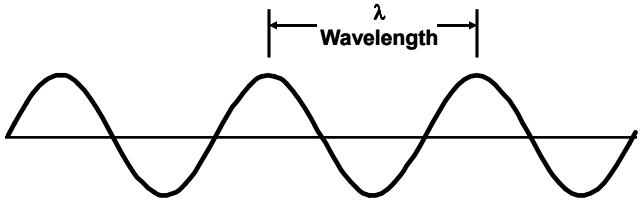
Laser radiation is <u>NOT</u> radioactive

Ref: Paul Daniel Jr

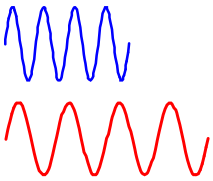
5

5

# Wave Nature of Light




Blue: λ = 400 nm



Red: λ = 700 nm

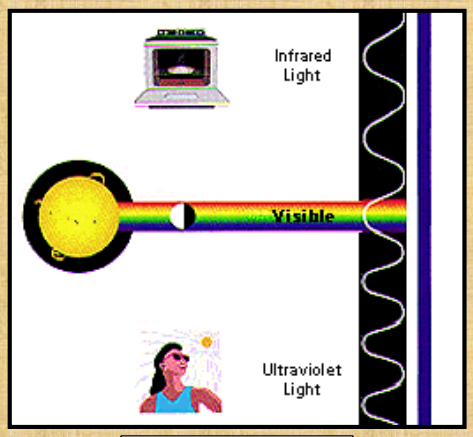
Light is an electromagnetic wave.

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

6

6

# Electromagnetic Spectrum




Drawing from NASA

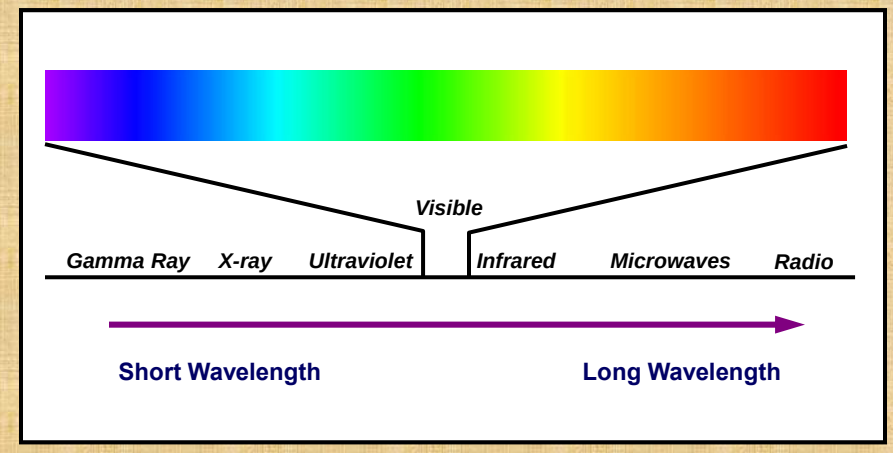
Ref: Paul Daniel Jr

**Lasers generate light in the ultraviolet, visible and infrared regions of the electromagnetic spectrum.**

| Region | Wavelength | Lasers |
|---|---|---|
| Far Infrared | 1400 to $10^6$ nm | $CO_2$ |
| Near Infrared | 700 to 1400 nm | Nd:YAG<br>Diode |
| Visible band | 400 to 700 nm | Ruby<br>Diode<br>HeNe<br>Argon |
| Ultraviolet | 180 to 400 nm | Excimer |

7

# Electromagnetic Spectrum




**Typically, lasers operate in the ultraviolet, visible, and infrared regions.**

8

8

# Invisible Laser Beams

- Many material processing lasers like Nd:YAG and $CO_2$ have **invisible laser beams.**
- Any laser that is below 400nm or above 700nm is considered invisible.
- The invisible laser beams may be seen with IR viewers or IR detectors.
- What we can **"see"** is the vaporized material glowing in the laser beam – not the beam itself.

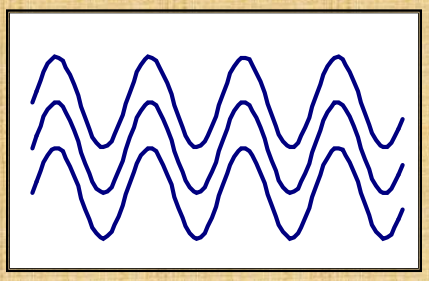
Ref: Paul Daniel Jr

9

9

# Laser Basics

- Laser light is different than ordinary light in three ways:
  - **Monochromatic**
  - **Directional**
  - **Coherent**
- Lasers are capable of posing a hazard because they can focus a large amount of energy onto a small area.



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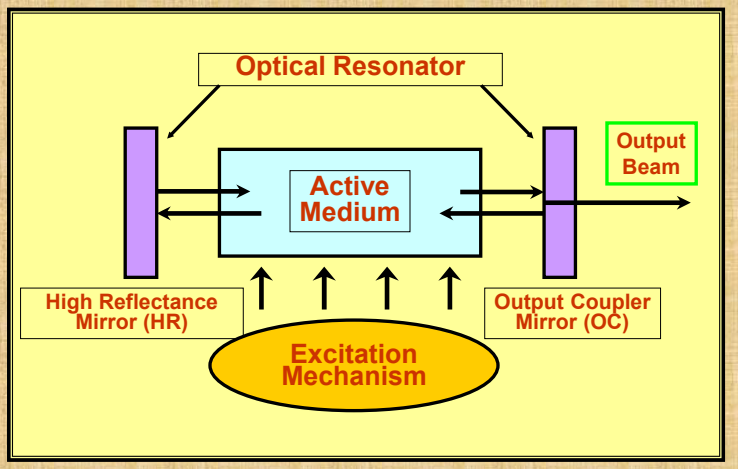
10

# Basic Laser Design




11

11

# Common Modes of Lasers

- **Continuous wave (CW):** Laser emits a steady beam of light.
- **Pulsed:** Emit laser light in an off-and-on or pulsed manner.
- **Q-switched:** A quartz crystal controlled by Radio Frequency to create extremely short pulses by blocking the rear mirror.

12

12

# Laser Pointers and Laser Sensors

How Hazardous are Laser Pointers and Laser Sensors?
(Class 1, 2, 3A or 3R)
Do Not Stare Directly into the Laser Beam!

- Eye injury is unlikely due to people's aversion to bright light and the eye's constant movement.
- Laser pointers can distract someone and cause injury.
- Orange and red laser pointers (632 nm to 670 nm) are less hazardous than green laser pointers.


Extra Precaution is needed when using a Green Laser Pointer (532nm)
- Green light is absorbed easier by your retina than orange or red light.

Ref: Paul Daniel Jr

13

13

# Laser Applications

- **Cutting** – metals, plastics and other materials
- **Drilling** – metals, plastics and other materials
- **Welding** – various metals and plastic bonding
- **Marking** – golf clubs, engraving, leather
- **Military** – direct energy weapon, targeting, tracking
- **Communications** – service providers
- **Entertainment** – light shows
- **Construction** – surveying and leveling
- **Nondestructive Testing**
- **Soldering**
- **Metrology** – measurements
- **Heat Treating**
- **Scribing**
- **Barcode Reading**


14

14

# Laser Classifications

**An indication of the beam hazard level of a laser or laser system during normal operations. The hazard level of a laser or laser system is represented by a number or a numbered capital letter.**

15

# Class 1

**Class 1 Laser Product**

- **Safe during normal use**
- **Incapable of causing injury**
- **Low power or enclosed beam**


Recommend guard removal warning sign

May be higher Class during maintenance or service

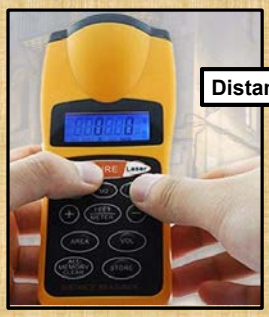
Nd:YAG Laser Marker

16

16

# Class 2 and 2M

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



Distance Finder


Barcode Scanners


17

17

# Class 3R Formerly 3a

- Aversion response may not provide adequate eye protection
- Laser user must recognize hazard and avoid direct eye contact
- CW maximum power (visible) 5 mW

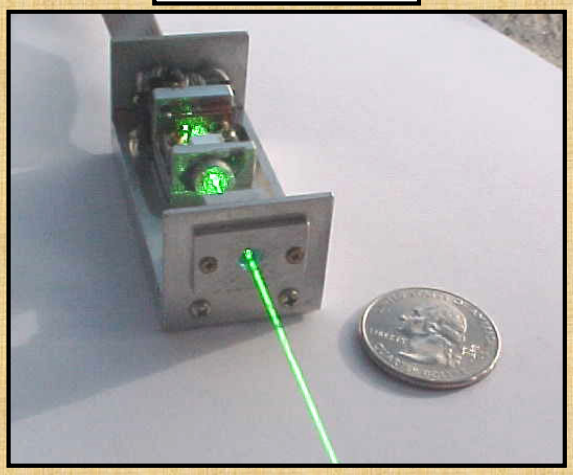
Laser Pointers


18

18

# Class 3B

DPSS Laser with cover removed



Courtesy of Sam's Laser FAQ, www.repairfaq.org/sam/lasersam.htm, © 1994-2004

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


19

19

# Class 4

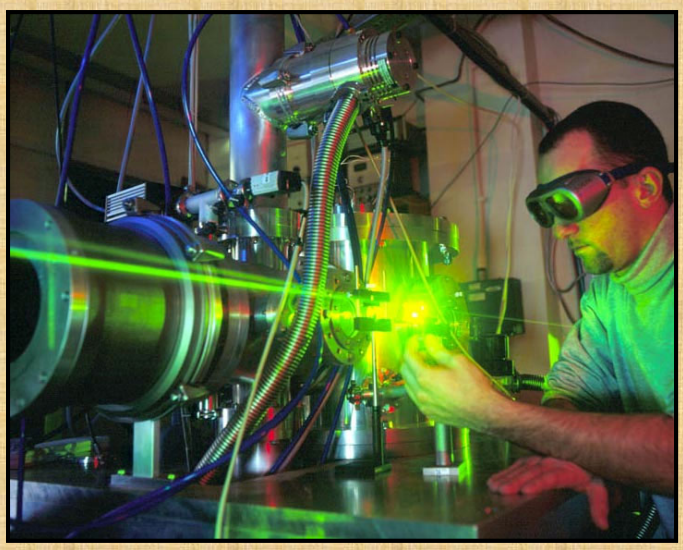


Photo: Keith Hunt - www.keithhunt.co.uk
Copyright: University of Sussex, Brighton (UK)

- Exposure to direct beam and scattered light is eye and skin hazard
- Can be visible or invisible
- CW power >0.5 W
- Fire hazard



20

| Laser Class | Laser Hazards | Product Examples |
|---|---|---|
| 3B | Immediate skin hazard from direct beam and immediate eye hazard when viewed directly. | . Industrial lasers<br>. Research lasers |
| 4 | Immediate skin and eye hazards from exposure to either the direct beam or the diffuse reflection; may also present a fire hazard. | . Industrial lasers<br>. Research lasers<br>. Medical device lasers for eye surgery or skin treatments |

21

21

# Changes to American National Standards Institute (ANSI) Laser Classifications in Z136.1

**In 2000 there were 6**

- Class 1
- Class 2A
- Class 2
- Class 3A
- Class 3B
- Class 4

**Since 2007 there are 7**

- Class 1
- **Class 1M**
- Class 2
- **Class 2M**
- **Class 3R**
- Class 3B
- Class 4

22

22

## Why change the classifications?

To harmonize National ANSI Z136.1 and the International IEC 60825 laser standards

23

23

## Lasers Classified Under Previous Standards

- Previously labeled **Class 3A lasers are now Class 3R** (if the beam is < 7 mm)
  - If the emergent beam diameter was > 7 mm, they could be Class 1M or 2M if reassessed
- ***NOTE: There is no requirement to reassess lasers previously classified***
  - ***Previous classification system was more conservative***

24

24

# Laser Hazards

25

## Laser Hazard Types

- **Laser Radiation** – eye and skin exposures (from the beam)
- **Non-Laser Radiation (NLR)** – electrical and EMF, chemical, flammables / combustibles, Optical Radiation (plasma emissions, UV, Blue Light)
- **Note:** This applies to Class 3B and 4 lasers

Eye Exposures

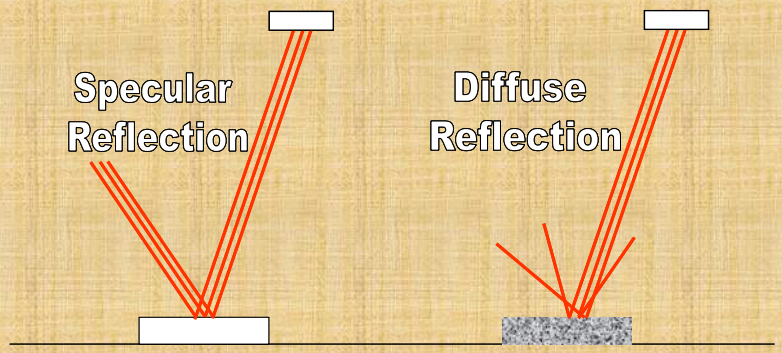
Wrist burn 2nd degree

Ref: Paul Daniel Jr

26

26

## Beam Hazards from Reflection




27

27

## Beam Hazards Resulting in Biological Damage

- Can be:
  - **Thermal (heat)**
  - **Photochemical**
  - **Acoustic**
- Primary Sites of Damage
  - Eyes
  - Skin

28

28

# Biological Damage Explained

- **Thermal (Heat/Burns)**
  - Caused by elevated temperature after absorption of laser energy.
  - Occurs in both eyes and skin.
  - Happens at all laser wavelengths.
  - Most common injury for most CW and long pulse lasers.

29

29

# Biological Damage Explained

**Photochemical**

- Photon interaction with molecules caused by chemical reactions after absorption of high energy photons.
- Occurs in both eyes and skin.
- Dependent on wavelength, must be less than 600nm.
- Most common for blue and UV wavelength exposures longer than ten seconds.

30

30

# Biological Damage Explained

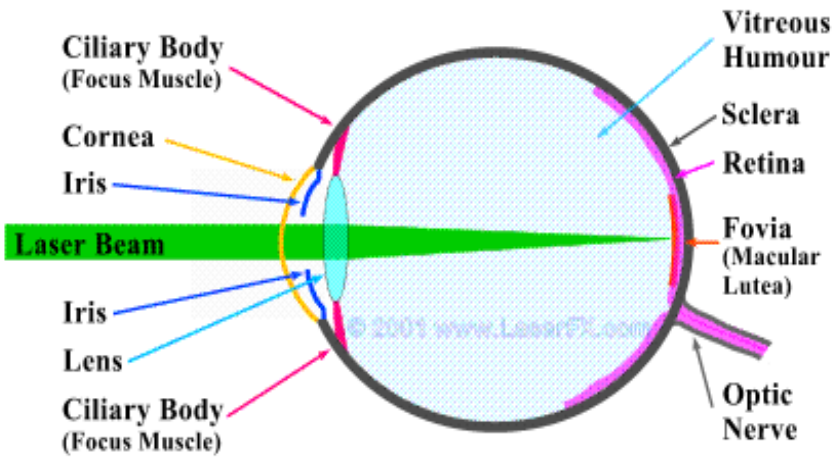
**Acoustic**

- Explosive retinal injury from short laser pulses less than 18ms visible and 50ms near infrared.
- Happens most often in visible and near infrared wavelengths less than 600nm.

31

31

## Simplified Cross Section of the Human Eye




Laser beams are almost parallel thus the eye's lens will focus them down to a small spot causing retinal burns.

32

32

# Definitions of Adverse Effects

**Photokeratitus** - A cornea burn caused by ultraviolet (UV) rays.

**Cataract** – A clouding of the lens in the eye.

**Photoretinitis** - Damage to the retina from exposure to intense light.

**Photodisruption** - Retinal hemorrhage from a short-pulsed laser, such as Q-switched, Ytterbium Fiber, Vanadate, Femtosecond.

Ref. Paul Daniel Jr.

33

33

# Signs and Symptoms of Adverse Effects

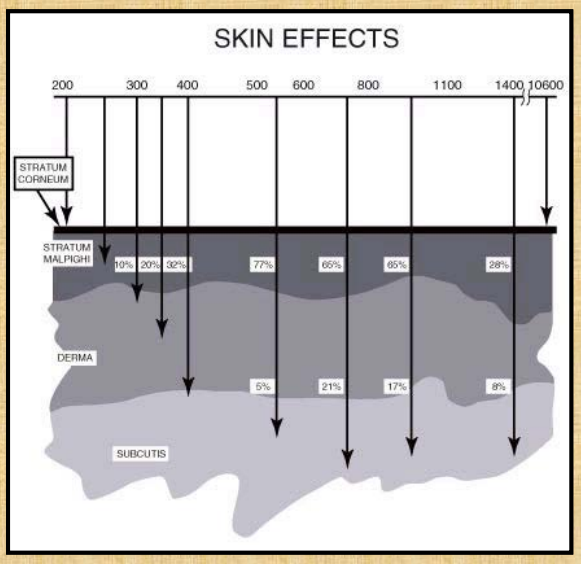
- **Eye Exposure**
  - Headache
  - Excessive watering
  - Sudden appearance of floaters in vision
  - Gritty feeling
  - Burning pain
  - After-image of color flash's complementary color
  - Difficulty detecting blue or green
  - Audible "pop" at exposure

34

34

# Skin Damage

- UV-C (200 – 280 nm): sunburn
- UV-B (280 – 315 nm): accelerated skin aging, increased pigmentation
- UV-A (315 – 400 nm): pigment darkening, photosensitive reactions
- Visible (400 – 780 nm): photosensitive reactions, skin burn
- Infrared (900 nm – 1 mm): skin burn




Skin depth chart by Dr. Dave Sliney

Source: http://www.lbl.gov/ehs/pub3000/CH16.html

35

35

# Non-beam Hazards

- Chemical
  - Organic dyes
  - Solvents
  - Gases
  - Interaction of the laser with target materials
  - Coolants such as liquid Nitrogen
- Optical
  - Welding - UV and Blue Light

- Laser Generated Air Contaminants (LGAC)
  - Metallic fumes and dust
  - Chemical emissions
  - Ozone
- Inadequate ventilation
- Noise

36

36

## Non-beam Hazards

- Electrical/Lockout
  - Power sources
  - Stored energy (e.g. capacitor banks)
  - Lamps (high pressure arc lamps, filament lamps)
- Gas Cylinders
  - Storage
  - Use

- Fire hazards
  - Electrical circuits
  - Improper beam enclosures
  - Ignition of gases/vapors
  - Flammable dyes
  - Combustible materials

37

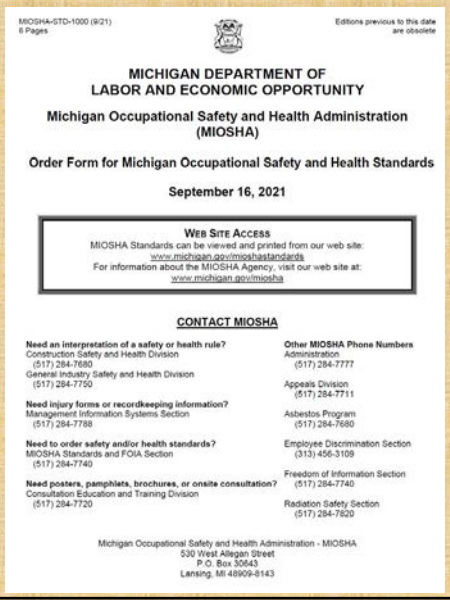
37

## MIOSHA Standards and Voluntary Compliance Information

- ✓ **MIOSHA Standards**
- ✓ **OSHA Tech Manual Section III**
  - **Chapter 6 Laser Hazards**
- ✓ **ANSI Z136.1-2022 *Safe Use of Lasers***

38

# GI MIOSHA Standards



MIOSHA-STD-1000 (9/21)
6 Pages

Editions previous to this date are obsolete

**MICHIGAN DEPARTMENT OF LABOR AND ECONOMIC OPPORTUNITY**

**Michigan Occupational Safety and Health Administration (MIOSHA)**

**Order Form for Michigan Occupational Safety and Health Standards**

**September 16, 2021**

**WEB SITE ACCESS**
MIOSHA Standards can be viewed and printed from our web site:
www.michigan.gov/mioshastandards
For information about the MIOSHA Agency, visit our web site at:
www.michigan.gov/miosha

**CONTACT MIOSHA**

**Need an interpretation of a safety or health rule?**
Construction Safety and Health Division
(517) 284-7680
General Industry Safety and Health Division
(517) 284-7750

**Need injury forms or recordkeeping information?**
Management Information Systems Section
(517) 284-7788

**Need to order safety and/or health standards?**
MIOSHA Standards and FOIA Section
(517) 284-7740

**Need posters, pamphlets, brochures, or onsite consultation?**
Consultation Education and Training Division
(517) 284-7720

**Other MIOSHA Phone Numbers**
Administration
(517) 284-7777

Appeals Division
(517) 284-7711

Asbestos Program
(517) 284-7680

Employee Discrimination Section
(313) 456-3109

Freedom of Information Section
(517) 284-7740

Radiation Safety Section
(517) 284-7820

Michigan Occupational Safety and Health Administration - MIOSHA
530 West Allegan Street
P.O. Box 30643
Lansing, MI 48909-8143

39

39

# GI MIOSHA Standards

- Part 1 General Provisions - pinch points, point of operation
- Part 2 Walking and Working Surfaces
- Part 6 Fire Exits - unobstructed egress
- Part 8 Portable Fire Extinguishers - inspections

- Part 12 Welding and Cutting - cylinder storage
- Part 14 Conveyors - nip points
- Part 18 Overhead and Gantry Cranes
- Part 26 Metal Working Machinery

40

40

## GI MIOSHA Standards

- Part 33 and 433 Personal Protective Equipment - PPE assessments
- Part 85 Lockout - energy isolation
- Part 39 Design Safety Standards For Electrical Systems - Electrical hazards are common – wires, conduit, control devices, outlets.
- Part 40 Electrical Safety Related work Practices - requirements for qualified workers
- Part 75 Flammable and Combustible Materials - storage and handling
- Part 92 Hazard Communication
- Part 301 Air Contaminants
- General Duty

41

41

## Part 681. Radiation In Construction: Ionizing and Nonionizing

- Requires qualified and trained employees to install, adjust, and operate laser equipment
- Proof of qualification in possession of operator
- Exposures > 5 mW require eye protection (See Table E-3)
- Protective goggles shall be labeled
- Areas posted with standard laser warning placards
- Only mechanical or electronic means shall be used as a detector for guiding the internal alignment of the laser
- Do not direct laser at employees
- Set up laser above head level when possible
- Label equipment to indicate maximum output
- Exposure limits: Direct staring <1 microwatt /$cm^2$, Incidental observing < 1 $mW/cm^2$, Diffused reflected light <2.5 $W/cm^2$

42

42

## Laser Safety Standards

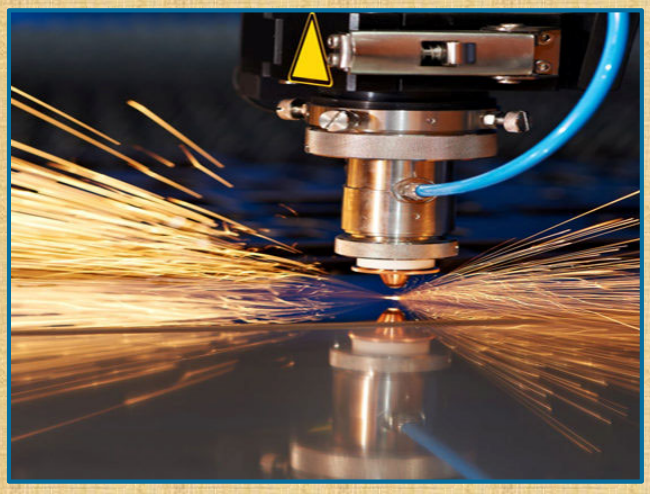
- The Federal Laser Product Performance Standard (FLPPS) of the Center for Devices and Radiological Health (CDRH). This federal law applies to the manufacturers of lasers.
- The American National Standard for Safe Use of Lasers ANSI Z136.1.
- International Electrotechnical Commission (IEC) – 60825 is the International Standard.

43

43

## Is ANSI Z136.1 a Legally Mandated Requirement?

- **Answer:** No. At the beginning of the ANSI Z-136.1 standard is the statement "The use of American National Standards is completely voluntary…"



44

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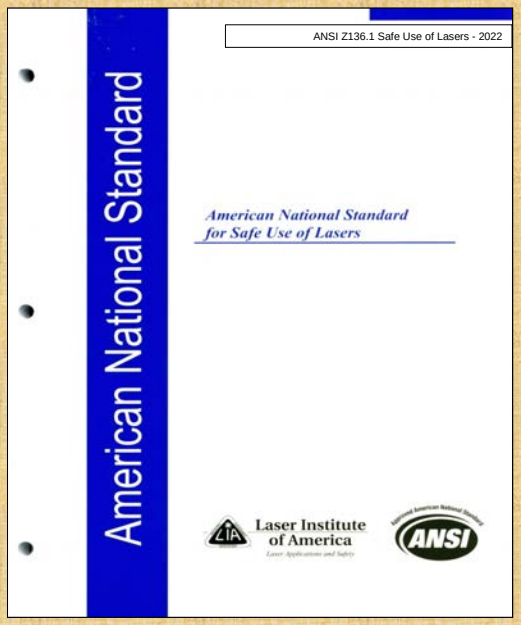



# ANSI Z136.1
# *Safe Use of Lasers*
# (2022)
# (most recent edition)

45

45

# American National Standards Institute (ANSI)

- Z136.1-2022, American National Standard for Safe Use of Lasers
- Z136.2-2012, American National Standard for Safe Use of Optical Fiber Communication Systems Utilizing Laser Diode and LED Sources
- Z136.3-2011, American National Standard for Safe Use of Lasers in Health Care
- Z136.4-2021, American National Standard Recommended Practice for Laser Safety Measurements for Classification and Hazard Evaluation
- Z136.5-2020, American National Standard for Safe Use of Lasers in Educational Institutions
- Z136.6-2015, American National Standard for Safe Use of Lasers Outdoors
- Z136.7-2021, American National Standard for Testing and Labeling of Laser Protective Equipment
- Z136.8-2012, American National Standard for Safe Use of Lasers in Research, Development, or Testing
- Z136.9-2013, American National Standard for Safe Use of Lasers in Manufacturing Environments
- ANSI B11.21-2006 (revised 2012). Safety Requirements for Machine Tools Using Lasers for Processing Materials.

46

46

# Photos from the Field

47

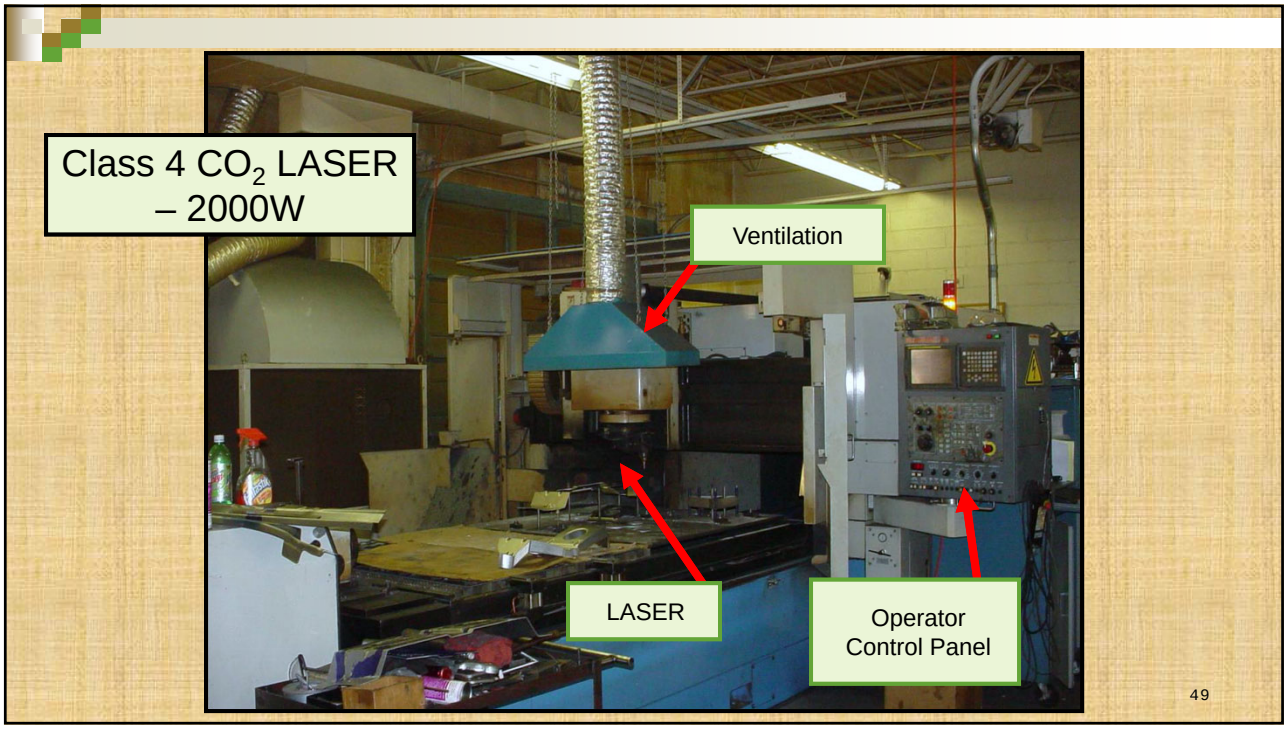
## Example: High Speed Engraving Laser

- Laser contained in a room by itself (Good)
- Laser Safety Officer needs to be assigned and trained
- Danger signage needs to be posted

**Class 4 Carbon Dioxide ($CO_2$) Laser**

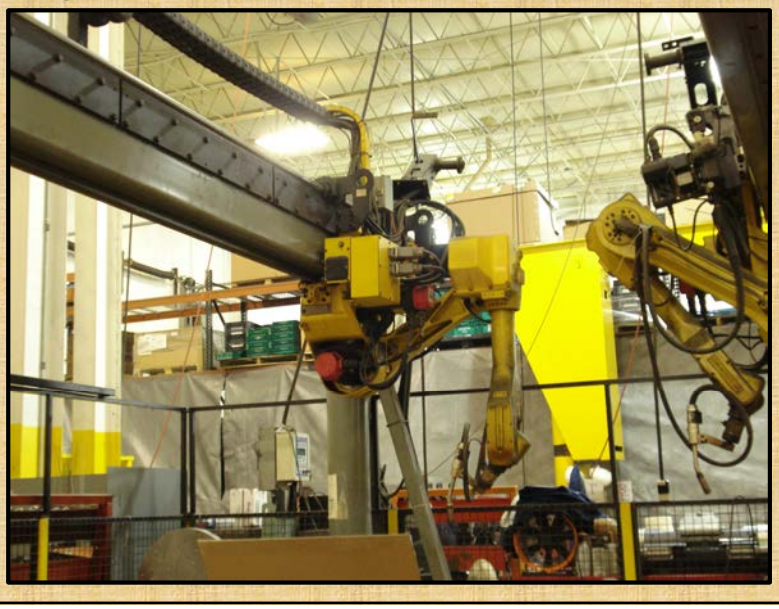
48

48




49

## Gantry Robot with Class 4 Laser Head




50

## Platform Guarding around Laser Facilitates Safe Filter Changes

51

51


What are the hazards to these employees?

52

52

53

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54

What is the hazard to this employee?

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## Anything Wrong?


56

56

## Anything Wrong?

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57

## After a CET Visit!


58

58

## Unguarded Laser

A Class 4 50 watt $CO_2$ laser is trimming an ink resistor on a circuit board:

- No guarding.
- Operator could touch the laser beam.
- Reflected laser beam could hit the operator or anyone near the laser.

Ref. Paul Daniel Jr.

59

59

## ✓Inspect Machines and Equipment


This smoked Lexan guard door was warped by a scattered $CO_2$ laser beam (1500 watts). Notice the hole in the lower right.

Ref. Paul Daniel Jr.

60

60

## ✓Inspect Machines and Equipment


A 1500-Watt CO2 welder with a smoked lexan guard door.

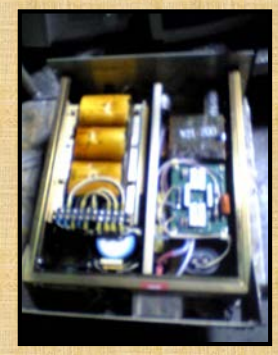
Ref. Paul Daniel Jr.

61

61

## Electrical Hazards

**This flashlamp pumped Nd:YAG cavity has the same voltage present as the power supply.**



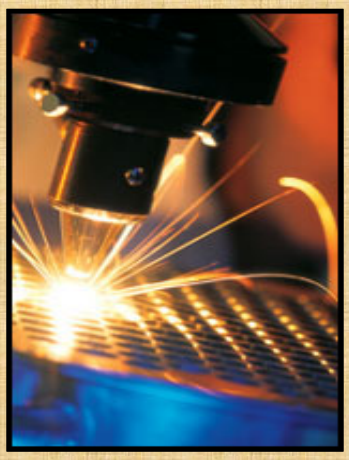
**Solid State Laser high voltage power supplies. Capacitors may hold their voltage for a long time after the power is disconnected from the machine. Check the maintenance manual for procedures to ground high voltage and check with a high voltage probe (left) to ensure that no voltage is present before working on the laser.**

Content: Paul Daniel Jr.

62

62

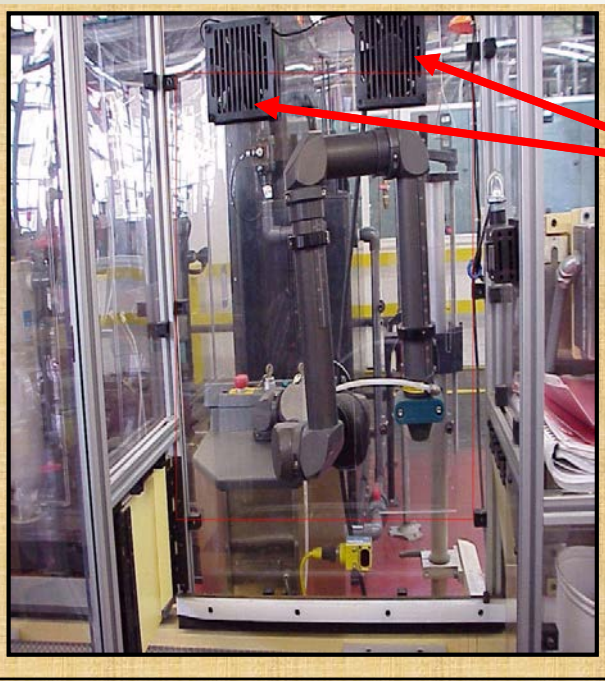
# Laser Generated Air Contaminants (LGACs)



- Non-metals also produce hazardous chemical vapors.
- ANSI Z136.1 (2014) Table G1. lists the possible LGACs produced based on the materials and laser used.
  - Table G1 removed in Z136.1 (2022)
- Ventilation and filtering systems may need to be implemented to control the LGACs.

63

63



The fans at the top of the guards are to remove Laser Generated Air Contaminants (LGAC), but they exhaust in people's faces.

From Paul Daniel Jr.

64

64

# Viewing Windows and Laser Safety Eyewear





- The optical density (OD) and Visible Luminous Transmission (VLT%) need to be considered when selecting the eyewear or window material.
- Minimum OD is calculated for the laser beam.
- Eyewear or filters that have a higher OD usually have a lower VLT%.

From Paul Daniel Jr.

65

65

# Blocking Barrier

- A blocking barrier, screen, or curtain which can block or filter the laser beam at the entryway should be used inside the controlled area to prevent the laser light from exiting the area at levels above the applicable maximum permissible exposure (MPE) level.

**Laser Protective Barriers and Curtains (Class 3B and or Class 4).**

From rli.com

66

66

## Enforcement Detail

- ✓Check Illness and Injury log form 300
- ✓Check for Laser Safety Officer (LSO)
- ✓Interview Employees
- ✓Inspect Equipment
- ✓Related Program

67

67

## Enforcement Detail

✓Inspect Machines and Equipment

**ACT 154**
Employer shall provide a workplace free of recognized hazards that would or could cause death or serious injuries.

68

68

# Enforcement Findings

✓Inspect Machines and Equipment

**PART 39**
Flexible cords and cables shall be connected to devices and fittings so that strain relief is provided

**PART 1**
The floor of a work area, passageway, or aisle shall be maintained free of slip and trip hazards

69

69

# Enforcement Findings

✓Inspect Machines and Equipment

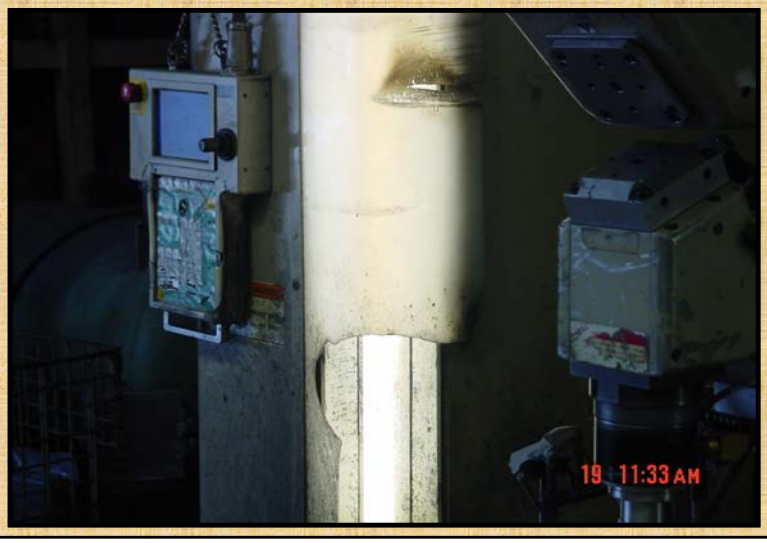
**Part 1**
A stop bar, stop button, electrical switch, or other mechanical device for the emergency stopping of machinery, excluding cables, shall be red in color.

70

70

## Enforcement Findings

✓Inspect Machines and Equipment

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## Enforcement Findings

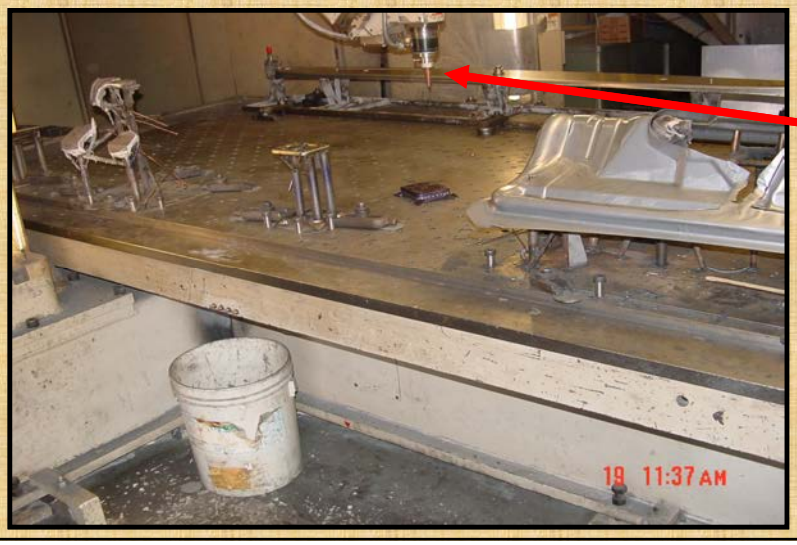
✓Inspect Machines and Equipment

72

72

## Enforcement Findings

✓Inspect Machines and Equipment




Enclosure of equipment or beam path is preferred

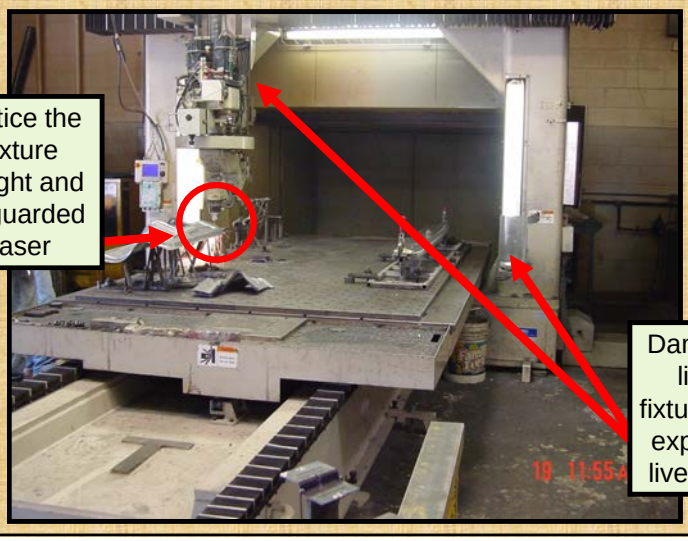
Beam height should be at level other than that for a sitting or standing person

73

73

## Enforcement Findings

✓Inspect Machines and Equipment



Notice the fixture height and unguarded laser

Damaged light fixture and exposed live parts

74

74

## Enforcement Detail

✓Interview Employees

- Verify Required Training
- Ask About Minor Injuries Such As Weld Flash or Sunburn
- Enforcement of PPE

75

75

## Enforcement Detail

✓Inspect Machines and Equipment

- Operating Condition/Location
- Guards/Shields/Beam Stops
- Signage
- Electrical Connections/Controls/ Interlocks
- Ventilation/Exhaust Hoods

76

76

# Laser Injuries and Related Accidents


77

## How Much Is Too Much?

- MPE = Maximum permissible exposure

  The level of laser radiation to which an unprotected person may be exposed to without adverse biological changes in the eye or skin.

78

78

## Skin Burn From $CO_2$ Laser Exposure

**Accidental exposure to partial reflection of 2000 w $CO_2$ laser beam from metal surface during cutting.**

79

79

## Argonne National Laboratory

A principal lab investigator developed a temporary lesion in his left eye when he was struck by a Class 4 laser beam while adjusting an unguarded beam splitter without wearing laser eye protection.

Because he neglected to cover the lateral ports, a stray beam bounced off the optic table and struck his unprotected left eye.

A safety review of the experiment was not conducted by a laser subject matter expert; therefore, the hazard of the beam being directed off the optics table was not identified.

80

80

## Colorado School of Mines

Government contractor at National Renewable Energy Laboratory (NREL) but working at Colorado School of Mines exposed a sample to laser radiation and was struck in the eye while trying to remove the sample. The worker was not wearing available eye protection. Worker reported seeing floaters and a yellowish-orange spot in field of view.

He received steroid injections to reduce inflammation and swelling. Follow-up exam showed a 500 μm burn spot in top retinal layer and a 200 μm burn area in second retinal layer. Worker returned to work with "no-laser" restriction. Vision is still 20-20 after recovery.

81

81

## Los Alamos National Laboratory

A student suffered permanent loss of central vision in her left eye when she looked directly into the path of a Class 4 laser beam while performing an unauthorized experiment with a principal lab investigator.

Following the principal lab investigator's example, the student looked into the target chamber, directly in the beam's path. Both the student and principal investigator believed the laser was not producing laser light.

The principal lab investigator routinely did not wear laser eye protection and trusted his ability to avoid the hazard. This failure to practice, model, and enforce safe behavior was transferred to the student and coworkers.

82

82

## Student Retinal Burn from Laser Beam

Student *WITH EYEWEAR* on (and witness to verify) received exposure from the rear mirror of a "Continuum" YAG laser.

The student was wearing Glendale Broadband (OD 4.0) eyewear; ANSI standard requires OD=6.0. Retinal burn resulted with permanent damage.

| | |
|---|---|
| Type: | Nd:YAG |
| Divergence: | |
| Wavelength: | 532 nm |
| Energy/Power: | 0.18/0.40 |
| Class 4 | |
| Pulse Rate: | 5 KHz |
| Exposure Time: | 7 ns |

83

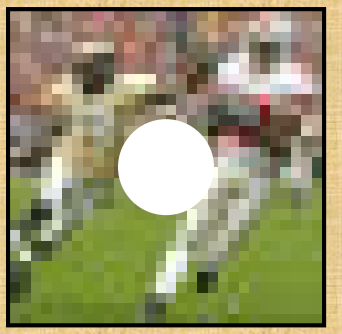
83

## Eye Damage: Focusing

### Remember: Your Eyes Are Designed to Focus

No Damage

Cornea Damage
BAD

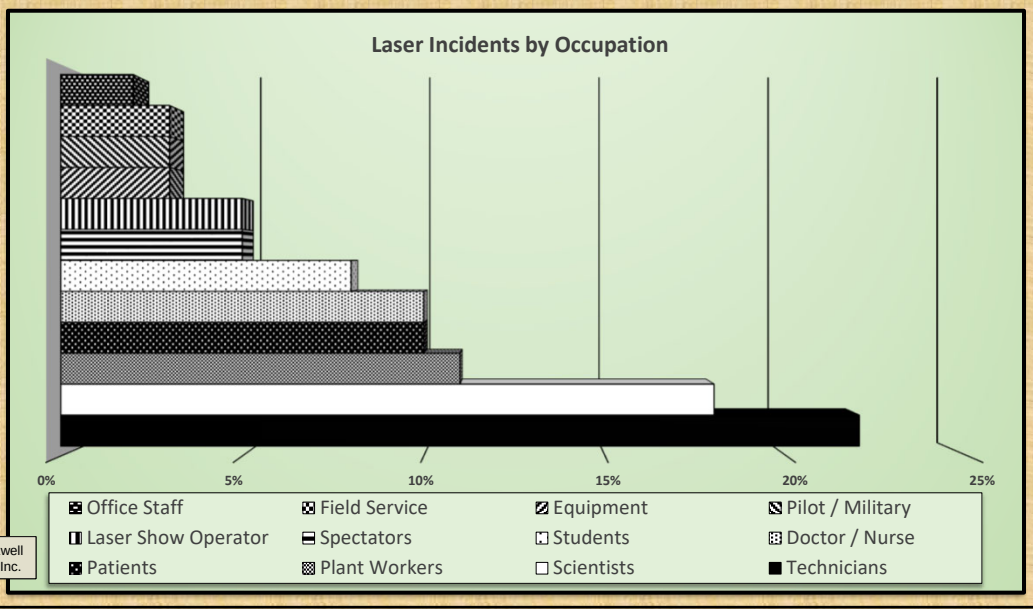


Retina Damage
WORSE

84

84

# Laser Incident Summary

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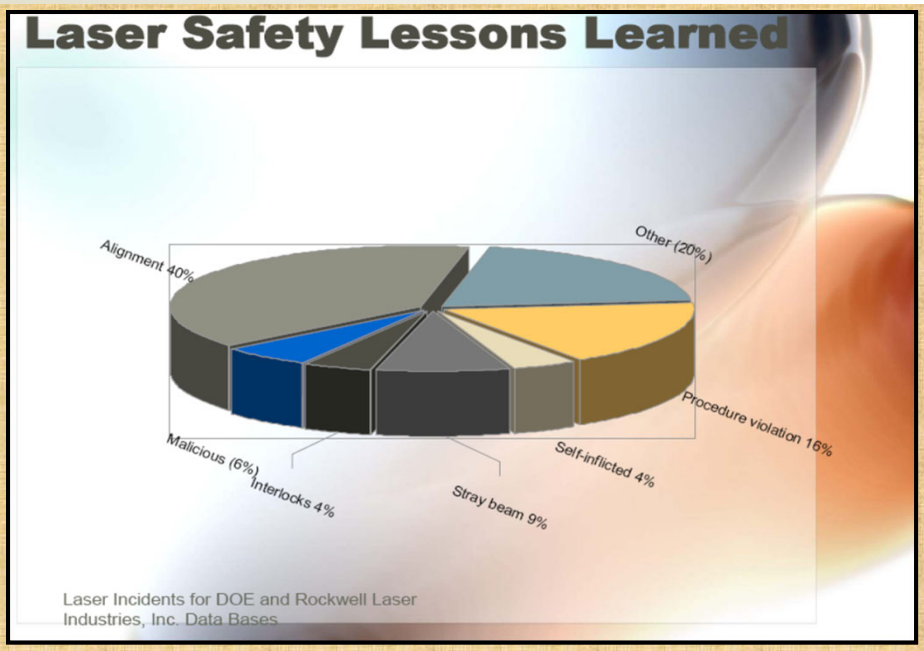
85

85

# Laser Safety Lessons Learned




86

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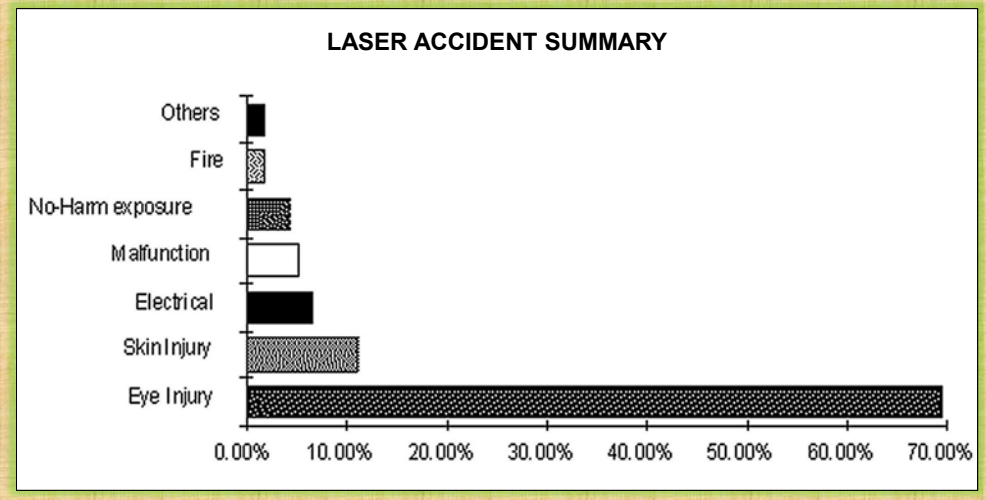
# Majority of Injuries Involve the Eye and to Lesser Extent the Skin




Summary of Reported Laser Accidents in the United States and their causes from 1964 to 1992

87

87

# Occupational Disease Reporting Form

- Part 56 of the Michigan Public Health Code requires physicians, hospitals, clinics, or employers to report all known or suspected cases of occupational diseases.

  ***Examples:*** Heatstroke, sunstroke, heat exhaustion, heat stress and other effects of environmental heat; freezing, frostbite, and other effects of exposure to low temperatures; decompression sickness; effects of ionizing radiation (isotopes, x-rays, radium); **effects of nonionizing radiation (welding flash, ultra-violet rays, lasers);** anthrax; bloodborne pathogenic diseases, such as AIDS, H4, hepatitis B or hepatitis C; brucellosis; malignant or benign tumors; histoplasmosis; coccidioidomycosis.

88

88

# Statistical Data for Rockwell Laser Institute Incident Database

### Most Common Lasers Producing Laser Related Incidents

| Laser Type | | % |
|---|---|---|
| Nd:YAG | | 29.7 |
| Argon | | 20.5 |
| CO2 | | 12.8 |
| Dye | | 9.9 |
| HeNe | | 7.0 |
| Ruby | | 6.2 |
| Unspecific | | 5.5 |
| Do. YAG/Ruby | | 3.7 |
| Other (HeCd,Cu..) | | 3.7 |
| Diode | | 1.1 |

### Occupations of Persons Involved in Incidents

| Occupation | | % |
|---|---|---|
| Technicians | | 21.3 |
| Scientists | | 17.6 |
| Patients | | 12.9 |
| Plant Workers | | 10.7 |
| Doctor/Nurse | | 9.2 |
| Students | | 8.4 |
| Spectators | | 4.8 |
| Laser Show Operators | | 4.0 |
| Pilot/Military | | 3.3 |
| Equipment | | 3.3 |
| Field Service | | 2.6 |
| Office Staff | | 1.8 |

Data through 2001 from www.rli.com

89

89

# Some Common Unsafe Practices:

- Not wearing protective eyewear during alignment procedures and in the laser control area
- Misaligned optics and upwardly directed beams
- Improper methods of handling high voltage
- Intentional exposure of unprotected personnel
- Lack of protection from non-beam hazards

90

90

## Some Common Unsafe Practices:

- Failure to follow Laser Safety Instructions
- Bypassing of interlocks, door and laser housing
- Insertion of reflective materials into beam paths
- Lack of pre-planning
- Turning on power supply accidentally
- Operating unfamiliar equipment
- Wearing the wrong eyewear

91

91

## Guidelines to Help Prevent Accidents During Alignment

- Only permit authorized personnel to be in the laser room or area.
- Laser protective eyewear will be worn.
- Be responsible for identifying and terminating each and every stray beam coming from that component.
- To reduce accidental reflections, watches and reflective jewelry should be taken off before any alignment activities begin.

92

92

## Guidelines to Help Prevent Accidents During Alignment

- The lowest possible/practical power must be used during alignments.
- Have beam paths that differ from the eye level when standing or sitting. Do not use paths that tempt one to bend down and look into the beam.
- All laser users must receive an introduction to the laser area by an authorized laser user of that area.
- Beam blocks must be used and must be secured.
- When the beam is directed out of the horizontal plane, it must be clearly marked.

93

93

## Laser Safety Officer (LSO) Responsibilities

94

## LSO Responsibilities from ANSI Z136.1

**(Class 3B and 4 Lasers)**

- Specify control measures
- Approve operating procedures and safe operating practices
- Specify and approve protective equipment (e.g. laser eyewear)
- Approve signs and labels
- Approve facilities, equipment and any modification to existing systems
- Perform periodic laser safety audits
- Assure proper training
- Monitor medical surveillance
- Confirm or determine laser classification

95

95

## LSO Responsibilities from ANSI Z136.1

**(Class 3B and 4 Lasers)**

- Provide laser safety consulting service
- Establish and update laser safety policies and related issues
- Has the authority to terminate unsafe laser operations
- Maintain records
- Investigate and report laser accidents
- Accompany regulatory investigators
- Laser safety committee
- Perform hazard evaluation

96

96

# Hazard Analysis / Control Measures

97

## Nominal Hazard Zones (NHZ)

- The space within which the level of the direct, reflected or scattered radiation may exceed the applicable Maximum Permissible Exposure (MPE).
- Exposures that occur beyond the boundary of the NHZ are below the appropriate MPE.

98

98


**EasyHaz** - hazard calculation software available through Kentek.

**LAZAN** - hazard calculation software available through Rockwell Laser Inc.

**Laser Hazard Evaluator** - hazard calculation software available through Laser Institute of America.

EASY-HAZ™
Laser Hazard Analysis Software
LSO EDITION

THE EVALUATOR
LASER SAFETY HAZARD ANALYSIS SYSTEM

99

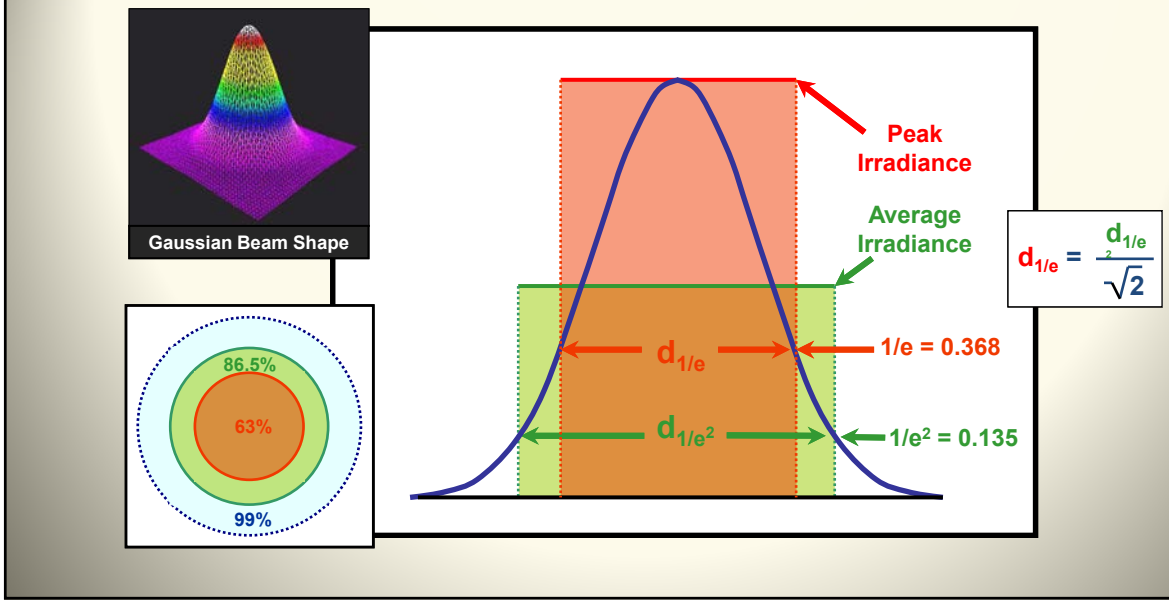
# Data Needed for Hazard Calculations

- Wavelength for each laser (nm or microns)
- Max power (watts) or peak pulse energy (Joules)
- Beam diameter (mm)
- Beam divergence (mrad)
- Laser type
- Continuous wave (CW)
- Single pulse
- Multiple pulse
- Pulse duration(s)
- Exposure time(s)

100

100

# Beam Diameter




101

# Exposure Duration for Intrabeam Hazard Analysis

## Visible Lasers

**0.25 second** — Eye aversion response to bright visible light

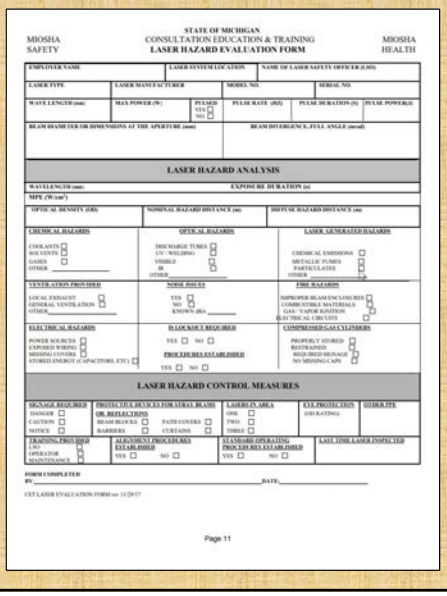
## Invisible Lasers

**10 seconds** — Maximum exposure time for near infrared wavelengths due to natural eye movements.

102

102

# Sample Laser Hazard Evaluation Form



STATE OF MICHIGAN
MIOSHA SAFETY — CONSULTATION EDUCATION & TRAINING — MIOSHA HEALTH
LASER HAZARD EVALUATION FORM

EMPLOYER NAME | LASER SYSTEM LOCATION | NAME OF LASER SAFETY OFFICER (LSO)
LASER TYPE | LASER MANUFACTURER | MODEL NO. | SERIAL NO.
WAVE LENGTH (nm) | MAX POWER (W) | PULSED YES NO | PULSE RATE (HZ) | PULSE DURATION (S) | PULSE POWER (J)
BEAM DIAMETER OR DIMENSIONS AT THE APERTURE (mm) | BEAM DIVERGENCE, FULL ANGLE (mrad)

LASER HAZARD ANALYSIS

WAVELENGTH (nm) | EXPOSURE DURATION (s)
MPE (W/cm²)
OPTICAL DENSITY (OD) | NOMINAL HAZARD DISTANCE (m) | DIFFUSE HAZARD DISTANCE (m)

CHEMICAL HAZARDS: COOLANTS, SOLVENTS, GASES, OTHER
OPTICAL HAZARDS: DISCHARGE TUBES, UV / WELDING, VISIBLE, IR, OTHER
LASER GENERATED HAZARDS: CHEMICAL EMISSIONS, METALLIC FUMES, PARTICULATES, OTHER
VENTILATION PROVIDED: LOCAL EXHAUST, GENERAL VENTILATION, OTHER
NOISE ISSUES: YES, NO, KNOWN dBA
FIRE HAZARDS: IMPROPER BEAM ENCLOSURES, COMBUSTIBLE MATERIALS, GAS / VAPOR IGNITION, ELECTRICAL CIRCUITS
ELECTRICAL HAZARDS: POWER SOURCES, EXPOSED WIRING, MISSING COVERS, STORED ENERGY (CAPACITORS, ETC.)
LO/TO LOCKOUT REQUIRED: YES, NO; PROCEDURES ESTABLISHED: YES, NO
COMPRESSED GAS CYLINDERS: PROPERLY STORED, RESTRAINED, REQUIRED SIGNAGE, NO MISSING CAPS

LASER HAZARD CONTROL MEASURES

SIGNAGE REQUIRED: DANGER, CAUTION, NOTICE
PROTECTIVE DEVICES FOR STRAY BEAMS OR REFLECTIONS: BEAM BLOCKS, PATH COVERS, BARRIERS, CURTAINS
LASERS IN AREA: ONE, TWO, THREE
EYE PROTECTION: OD RATING(S)
OTHER PPE
TRAINING PROVIDED: LSO, OPERATOR, MAINTENANCE
ALIGNMENT PROCEDURES ESTABLISHED: YES, NO
STANDARD OPERATING PROCEDURES ESTABLISHED: YES, NO
LAST TIME LASER INSPECTED

FORM COMPLETED BY _____ DATE _____

CET LASER EVALUATION FORM rev 11/29/17

Page 11

Industrial Laser Compliance Guide SP #39

103

103

# Laser Hazard Analysis- EasyHaz

- Exposure parameters
  - Wavelength: 10.6 µm
  - Power: 2000 W
  - Beam diameter: 18 mm
  - Beam divergence: 1.5 mrad
  - Exposure time: 10 s
- Calculated values
  - MPE: 0.1 W/cm$^2$
  - Eyewear OD: 5.32
  - Intrabeam NOHD: 1500 m
  - Diffuse Reflection NHZ: 0.80 m

104

104

# EasyHaz Screenshot

| LASER PARAMETERS | | |
|---|---|---|
| Wavelength (um) | 10.6 | |
| | Continuous | |
| Power (W) | 2000 | Average |
| Exposure Time (s) | 10 | |
| | | Entry Ignored |
| | | Entry Ignored |
| | (1/e^2) | |
| Diameter (mm) | 18 | |
| Divergence (mrad) | 1.5 | |

| REPORT | | |
|---|---|---|
| Ocular MPE (W/cm^2) | 1.00e-1 | |
| Eyewear (OD) | 5.318 | worst case |
| Diffuse NHZ (m) | 7.98e-1 | worst case |
| Intrabeam NOHD (m) | 1.50e+3 | worst case |

Easy Haz Basic is intended for educational and informational purposes and is not a substitute for a knowledgeable and trained Laser Safety Officer as required by ANSI Z136.1 American National Standard for Safe Use of Lasers.

105

105

# EasyHaz Calculation Results

- Maximum Permissible Exposure (MPE)
- Optical Density (OD) for Eyewear
- Nominal Hazard Zones (NHZ) – an area where an exposure may exceed the MPE.
- Intrabeam Nominal Optical Hazard Distance (NOHD)
- Diffuse NHZ

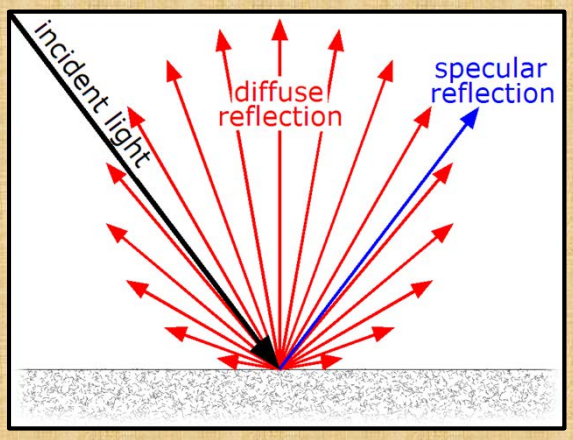



Image is from Wikipedia at https://www.google.com/search?q=laser+diffuse+reflectionandrlz=1C1GGRV_enUS751US751andsource=lnmsandtbm=ischandsa=Xandved=0ahUKEwik46z3ouTXAhWI5lMKHSUnDE0Q_AUICigBandbiw=1280andbih=617#imgrc=uxB980or3E5RhM:

106

106

# Case Study Activity

107

# Engineering Controls

108

# Engineering Controls

**Enclosures**

- Enclosed Beam Path
  - Inside a protective enclosure
  - Interlocks
  - Labels on laser head
  - Removable panels or access doors
  - Beam access prevented


109

109

# Engineering Controls

- Local exhaust ventilation
- Elimination of reflective surfaces
- Shutters
- Remote firing controls

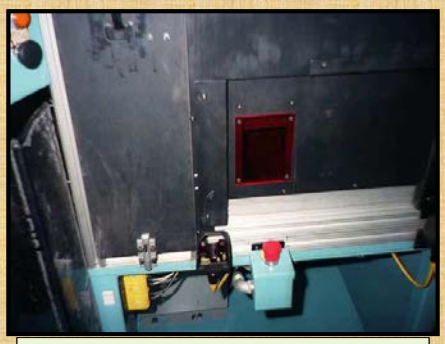
110

110

# Laser Safety Viewing Ports

- Viewing ports are made of filter material that reduces the laser beam hazard below the MPE and allows viewing of the laser work.
- The OD and wavelength of the filter material shall be labeled on the machine and meet the manufacturer's requirements.


Green viewing ports for Nd:YAG laser



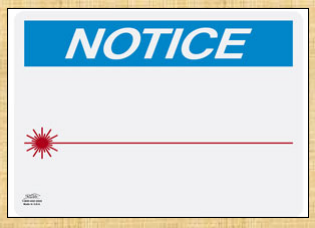
Polycarbonate material viewing port ($CO_2$ laser)

111

111

# Temporary Laser Controlled Area

- Set up guards around the laser that protect personnel outside the guards.
- Post ANSI Notice - Laser in Service signs on the guards.

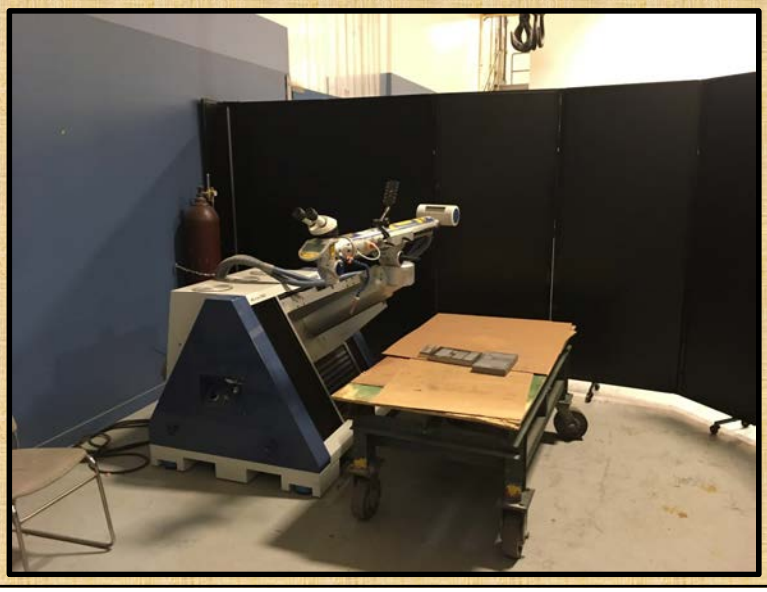



Note: this is not a good laser barrier because of the gap between the two panels. A proper barrier needs to have a burn through limit (BTL) or LSO approval.

112

112

## Temporary Laser Enclosure



113

113

## Temporary Laser Enclosure


114

114

# Class 4 Entryway Controls

1. Non-Defeatable Entryway Controls
   - Doorway interlock is non-defeatable
   - Training of authorized users only
2. Defeatable Entryway Controls
   - Doorway interlock is defeatable
   - Training of all personnel with access
   - Barrier and eyewear at door
3. Procedural Entryway Controls
   - No doorway interlock
   - Training of all personnel with access
   - Barrier and eyewear at door
   - Visible or audible signal at doorway

115

115

# Administrative and Procedural Controls

- Laser Safety Officer
- Written Standard Operating Procedures (SOPs)
  - Maintenance
  - Alignment Procedures
- Training
- Protective Devices
- Spectator Limits
  - Warning Signs

116

116

# Required Signage

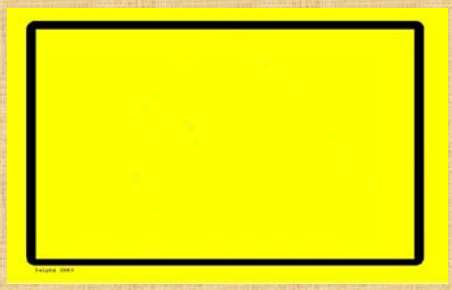







# IEC Logotype Signs for all laser classes (except Class 1 systems)

Logotype sign (no words)



Data label

# Personal Protective Equipment

**Laser safety eyewear**:

- Is available in glass or plastic lenses
- In the U.S.(falls under ANSI Z136.1) and is labeled with the optical density (OD) rating and wavelength for which it provides protection
- **Would have prevented most of the reported laser eye injuries**

119

119

# EN (European) Laser Safety Eyewear Standards

- EN laser eyewear is thick and does not have the same markings, as the ANSI Z136.1 Laser eyewear does in the United States (U.S.)
- Testing standards are different from ANSI Z136.1 and require actual laser stability testing (with the beam hitting the eyewear) for at least ten seconds CW or 100 pulses (pulsed modes).

**Reference:** https://noirlaser.com/laser-standards

120

120

## Personal Protective Equipment

- Clothing
- Laser Barriers and Protective Curtains
  - Used for area control
  - Should be rated for laser applications
  - Not a “welding curtain”

www.rli.com

121

121

## Laser Training Specifics

- **LSO**
- **Maintenance**
- **Operators**

122

# Laser Safety Training

In addition to the LSO, other employees are potentially exposed to laser hazards and require training based on the hazards:

- Maintenance employees
  - The scope of the training will depend on the level of potential exposure related to the task being performed
    - Is maintenance done in-house?
- Operators
- Others

123

123

EXAMPLE

**Laser Safety Awareness – Maintenance**

1. **Training** – All maintenance personnel shall complete Laser Safety Awareness – Maintenance training (CTIS 28586) and maintenance training on a specific Class 3B or Class 4 laser prior to servicing that laser. A person with laser experience may be referred to the LSO by their supervisor for exemption from some specific laser training. All contracted laser maintenance personnel shall follow the same procedures as a Delphi employee.
2. **Machine Specific Safety Information** – Review the operating procedure, maintenance procedure, Delphi laser data sheet (lsplac.xls) and the manufacturer's manual to identify the following before servicing the laser.
   A. Safe servicing practices.
   B. Location of high voltage and laser beam hazards.
   C. Check your laser safety eyewear for proper wavelength, optical density, visible light transmission percent and lens color.
3. **Laser Safety Eyewear** – Most laser that weld, drill, cut, trim, or mark have INVISIBLE LASER BEAMS. Cornea and retina burns may result from laser beam contacting the eye. ALWAYS WEAR THE SPECIFIED LASER SAFETY EYEWEAR ANYTIME THE LASER BEAM PATH IS OPEN.
4. **Temporary Laser Controlled Area** – Always construct a temporary laser-controlled area before opening guards that expose the laser beam. The temporary laser-controlled area shall be constructed with laser blocking barriers or curtains. A blue sign "NOTICE – Laser in Service" shall be posted on the barriers or curtains.

Paul Daniel Jr.

124

124

EXAMPLE

## Laser Safety Awareness – Maintenance (Continued)

5. **Lockout** – Follow Delphi Health and Safety lockout procedures.
6. **Machine Command Isolation** – If possible, disconnect the automation interface connector and use a manual control box to control the laser during alignments. Reconnect the automation to run parts to complete the alignment and focus.
7. **High Voltage**
   A. Remove all jewelry and conductive objects before working on the laser.
   B. Place non-conductive rubber mats on the floor near the high voltage sections of the laser.
   C. Do not stand in water.
   D. HIGH VOLTAGE POTENTIAL MAY STILL BE PRESENT WITH THE DISCONNECT OFF. Review the grounding and capacitor shorting procedures in the manufacturer's manual and/or maintenance procedure. After the grounding and/or shorting use a high voltage probe to check high voltage points for zero potential. Try to work with another electrically knowledgeable person.
8. **Flashlamps** – Lasers that use FLASHLAMPS have High Voltage and Glass Breakage hazards (example Nd:YAG laser). Place something over the flashlamp that can absorb exploding glass. The flashlamp gas is under pressure and the heat of operation could make it explode during the removal.
9. **Machine Ready for Operation** – Check that all guards are replaced and that no interlock is left bypassed or defeated.



125

EXAMPLE

## Laser Safety Awareness – Operator

1. **Training** – All operators shall complete Laser Safety Awareness – Operator training (CTIS 28587) before operating a machine that contains a Class 3B or Class 4 laser.
2. **Prior to Running the Machine** – Inspect the laser safety guards as identified in the operating procedures.
3. **Laser Safety Eyewear** – Most laser that weld, drill, cut, trim, or mark have INVISIBLE LASER BEAMS. Cornea and retina burns may result from laser beam contacting the eye. ALWAYS WEAR YOUR SPECIFIED SAFETY GLASSES OR LASER SAFETY EYEWEAR. The laser safety eyewear specification are on the Laser Safety Placard.
4. **Unsafe Machine Operation** – Stop the machine and move away, if you see any of the following:
   a. You can directly see the laser arc.
   b. You feel any abnormal heat on any part of your body.
   c. Your safety eyewear starts to distort or melt.

   Call someone to correct the laser safety guarding before restarting the laser machine.
5. **Temporary Laser Controlled Area** – Never enter a temporary laser-controlled area (barriers with posted "NOTICE – Laser in Service" signs) or you may contact with a laser beam or high voltage.



126

# Laser Resources and References

**Website Links**

127

## Laser Related Websites

**ANSI electronic Standards Store**

www.webstore.ansi.org/

**Kentek** (***Purchased Laser-Professionals***) Laser parts, eyewear, barriers, reference material and safety products and EASY-Haz laser hazard calculator.

www.kentek-laser.com/

**Rockwell Laser Industries (RLI)**

www.rli.com/

**Laser Institute of America (LIA)**

www.lia.org/

128

128

# Laser Related Websites

**MIOSHA CET**
www.michigan.gov/miosha

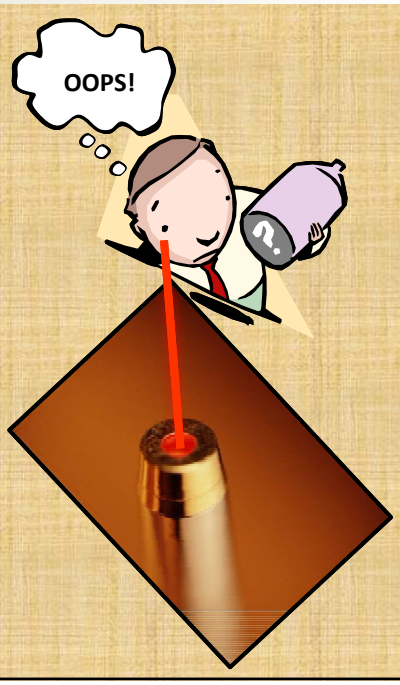
**Occupational Safety and Health Administration**
www.osha.gov

**OSHA Technical Manual Section III, Chapter 6 Laser Safety**
https://www.osha.gov/dts/osta/otm/otm_iii/otm_iii_6.html

129

129

# Questions?




130

130

# Assessment

- The purpose of this assessment is to validate the knowledge learned in class.
- Passing score of 70% correct is required.
- Class reference materials/books are not allowed to be used during the assessment.
- Collaboration/discussion with others is not allowed during the assessment.
- Answers will be reviewed after everyone completes and submits their assessment.

131

131

Thank you.

**Don't Forget to Take the Survey**

MIOSHA
Michigan Occupational Safety and Health Administration

132

# Understanding Industrial Laser Safety - Student Resources

**MIOSHA Standards: www.mi.gov/mioshastandards**

**CET Handouts:** Industrial Laser Compliance Guide (SP #39)

**Other resources:**

**Kentek Laser (Purchased Laser Safety Professionals) -**
Laser parts, PPE, reference material and safety products https://www.kenteklaserstore.com/

**Rockwell Laser, Inc** (Very good resource) - https://www.rli.com/

**Laser Institute of America** - Training, reference material, and hazard software https://www.lia.org/

**TJS Laser, Inc. (Quick response, good technically)** - Laser parts and laser repair.
https://www.tjslasers.com/

**Cascade Laser** - Laser parts https://cascadelaser.com/index.htm

**US Federal Product Specifications (English Only)**
https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/CFRSearch.cfm?fr=1040.10
https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/CFRSearch.cfm?fr=1040.11

**OSHA Technical Manual Section III, Chapter 6 Laser Safety** https://www.osha.gov/dts/osta/otm/otm_iii/otm_iii_6.html

**OSHA Guidelines for Laser Safety and Hazard Assessment (Pub 8-1.7 – OSHA Archive)**
https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_id=1705&p_table=DIRECTIVES

**Flashlamp, Arc Lamp and UV Curing Light Considerations**
https://www.hilltech.com/safety.html

**EN 207 (European laser eyewear) Markings Explained**

After testing to EN 207 the laser protective eyewear is awarded various markings which are printed on the eyewear and specify the maximum power and energy densities which the eyewear can protect against at different wavelengths.
https://www.lasermet.com/resources/en207_safetyeyewear.php

## MIOSHA Training Institute (MTI) Resources:
www.michigan.gov/mti

## MIOSHA Training Calendar:
www.michigan.gov/mioshatraining

## MIOSHA Homepage:
www.michigan.gov/miosha


Michigan Department of Labor and Economic Opportunity
Michigan Occupational Safety and Health Administration
Consultation Education and Training Division
525 W. Allegan St., P.O. Box 30643
Lansing, Michigan 48909-8143

For further information or to request consultation, education and training services
call 517-284-7720
or
visit our website at www.michigan.gov/miosha

www.michigan.gov/leo

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