LIGO-T960201-00-V

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NO. V049 - PL - 133

PROJECT CORRESPONDENCE

FAX **LETTER** **DATE:** 3/27/96

cc: Cecil Franklin
Allen Sibley
John Worden

TO: **California Institute Of Technology**
391 South Holliston Avenue
Pasadena, CA 91125
C/O Ms. Linda Turner/LIGO DCC
LIGO Project MS-51-33

ATTENTION:

The following documents are attached:

EDWARDS HIGH VACUUM PUMP MANUALS;
STPH 2000 C TURBO MOLECULAR PUMP
QDP DRYSTAR VACUUM PUMPS
EH MECHANICAL BOOSTER PUMPS
EDP 200 CHEMICAL DRY VACUUM PUMPS
EXT TURBO MOLECULAR PUMPS
EXH TURBO MOLECULAR PUMP CONTROLLERS

Comments:

Signed By: J Mottar

cc: LIGO File

Laser Safety Training Program

Student Workbook

Developed by

Interactive Media Communications
204 Second Avenue
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(617) 890-7707

Table of Contents

COURSE INTRODUCTION

This course provides instruction on lasers and laser safety. The course is divided into five videotape segments. You may use a single tape or a series of tapes depending on your specific training needs. The course begins with information on the general characteristics of lasers and how they work, followed by information on the hazards of lasers. The instruction covers the various classes of lasers and the environments in which they are found—manufacturing, laboratory, and service.

➤ Course Overview

This course is designed for:

- Individuals who work with any class of laser and want to learn more about laser safety techniques and practices.

The course consists of five videotapes covering the following topics:

Tape 1

- **Topic 1.1 Introduction to Laser Safety**—In this topic you will learn about the physics of lasers, including the properties of light, laser radiation, and how lasers work. In addition, you will be introduced to the general and practical concepts of lasers including types of lasers and their applications, laser classifications, laser equipment labels, and laser certification.
- **Topic 1.2 Laser Hazards**—In this topic you will learn the basic physiology of the eyes and skin, the ways in which you could be exposed to laser radiation, and the kinds of damage that might result from laser radiation exposure.

Tape 2

- **Topic 2.1 Class II and IIIa Lasers**—In this topic you will learn about the major characteristics of Class II and Class IIIa lasers. This topic also includes information on the hazards associated with these two classes of lasers as well as important safety precautions you should take while working with these lasers.
- **Topic 2.2 High-Powered Lasers**—In this topic you will learn about the major characteristics of high-powered lasers. This topic includes information on non-laser beam hazards, engineering, and procedural control measures you should know before working with high-powered lasers. It also provides general information about how fiber optics are used with lasers.

Tape 3

- **Topic 3.1 High-Powered Lasers in Manufacturing**—In this topic you will learn about high-powered lasers used in manufacturing and how to assure their safe use.

Tape 4

- **Topic 4.1 High-Powered Lasers in the Laboratory**—In this topic you will learn about the high-powered lasers used in the laboratory and how to assure their safe use.

Tape 5

- **Topic 5.1 Servicing High-Powered Lasers**—In this topic you will learn how to identify and avoid the hazards of servicing high-powered lasers.
- **Topic 5.2 Servicing Optical Fiber Communication Systems**—In this topic you will learn how to identify and avoid the hazards of servicing Optical Fiber Communication Systems.

Course Materials

Each topic contains two types of resources: a videotape and workbook. The videotape covers the topic content. For each topic, the workbook contains the following information:

- **Topic Introduction**—Highlights what the topic covers.
- **Learning Objectives**—Presents a checklist of statements describing what you should be able to do when you have completed the topic.
- **Directions for Proceeding**—Gives step-by-step instructions for watching the videotape and studying the subject matter.
- **Topic Exercises**—Provides the opportunity to apply what you learned and to discover additional information on the subject.
- **Topic Summary**—Summarizes information presented in the topic.

References

In addition, the workbook provides the following references:

- **Appendix A: Glossary**—Glossary of terms introduced in the course. Refer to this glossary whenever you need to check the definition of a key term.
- **Appendix B: Bibliography**—An annotated bibliography of documents and other resources on lasers and laser safety.

How to Take This Course

If you are taking this course with an instructor in a classroom, the instructor will guide you through the course.

If you are taking this course as a self-study, complete the appropriate workbook topics in numerical order. The tapes may be used individually or in sequence. Begin each topic by reading the Introduction, Learning Objectives, and Learning Resources. The Directions for Proceeding describe the order in which to use the learning resources.

How to Use the Topic Exercises

The workbook Topic Exercises are not intended as tests. Instead, view them as guides to help you identify key information, and learn how to put this information to work. Answer all

the questions as best you can, then follow the instructions for checking your answers. Make sure to read the additional information given with the answers. It will help you get the most from the course.

Reviewing the Videotape

If you wish, you can go back to review any of the videotape segments before proceeding to the next learning resource. Do this if you missed any of the important information or think that viewing the videotape segment again will help you understand it better. For example, you might want to review a videotape segment if you have difficulty completing the corresponding topic, or if you find that you answered a number of the questions incorrectly.

Tape 1

1.1 Introduction to Laser Safety
1.2 Laser Hazards

Topic 1.1
Introduction to Laser Safety

➤ Introduction

In this section you'll learn about the physics of lasers, including, the properties of light, laser radiation, and how lasers work. In addition, you'll be introduced to general and practical concepts of lasers including the types of lasers, their applications, laser classifications, laser equipment labels, and laser certification.

➤ Learning Objectives

When you have completed this section, you should be able to do the following:

- Identify the major characteristics of ordinary light.
- Identify the major characteristics of laser radiation.
- Identify the three major components of a laser.
- Define the acronym LASER.
- Identify the four major types of lasers based on the lasing medium.
- Identify the four major laser classifications.
- Recognize the various types of laser labels.
- Recognize the difference between a certified laser and one that is not certified for use.

➤ Learning Resources

- Videotape Topic 1.1: Introduction to Laser Safety
- Workbook Topic 1.1 Exercise
- Topic Summary

➤ Directions for Proceeding

✓ *Complete the following steps in order. You may want to check off each step as you complete it.*

___ 1. Read the workbook introduction to Videotape Topic 1.1.

___ 2. Watch Videotape Topic 1.1.

___ 3. Complete Topic 1.1 Exercise.

___ 4. Read the Topic Summary in this Workbook.

Topic 1.1 Exercise
Introduction to Laser Safety

✓ *Directions: Check or circle your answer(s) to each question. When you complete the exercise, fold over the right side of the page to check your answers, then, turn the page to get more information about each question. Remember, some questions may have more than one answer.*

1. A wavelength is defined as which one of the following?

   (Circle your choice.)

   A. The amount of time it takes for one wave to rotate completely.

   B. The distance that a wave travels during the time it takes to vibrate through one complete cycle.

   C. The distance that a wave travels forward during the time it takes to rotate completely.

   D. The length and width of the laser beam.

2. Which of the following is a reason why a light bulb is not a powerful source of energy?

   (Circle your choice.)

   A. Its waves radiate in all directions.

   B. Its waves radiate in one direction.

   C. It is monochromatic.

   D. It has very high irradiance.

3. Which of the following is NOT a property of laser radiation?

   (Circle your choice.)

   A. Monochromacity

   B. Coherence

   C. Directionality

   D. High divergence

Topic 1.1 Exercise
Introduction to Laser Safety

Answer	Additional Information
1. **B**	The distance that a wave travels during the time it takes to vibrate through one complete cycle defines its wavelength.
2. **A**	Waves from a lightbulb are non-directional while waves from laser radiation are directional and more powerful.
3. **D**	Laser radiation has <u>low</u> divergence.

4. Solids, liquids, and gases are examples of which one of the following?

   (Circle your choice.)

   A. An excitation system
   B. A lasing medium
   C. An optical resonator
   D. A laser property

5. The acronym "LASER" stands for which one of the following terms?

   (Circle your choice.)

   A. Light Amplification by Stimulated Emission of Radiation
   B. Light Amplification by Spontaneous Emission of Radiation
   C. Light Alteration by Stimulated Emission of Radiation
   D. Light Alteration by Spontaneous Energy of Radiation

6. By changing the dye in a dye laser you can change which of the following characteristics of the laser?

   (Circle your choice.)

   A. Coherence
   B. Direction
   C. Divergence
   D. Wavelength

Answer	Additional Information
4. B	The lasing medium is the substance that is energized in order to get its electrons to emit light.
5. A	The acronym LASER, Light Amplification by Stimulated Emission of Radiation, summarizes the basic physics of how laser light is produced.
6. D	The lasing medium, in this case, a dye, determines the laser's wavelength.

7. Which class of laser would be considered safe if not viewed longer than the eye's aversion response?

   (Circle your choice.)

   A. Class II
   B. Class IIa
   C. Class IIIb
   D. Class IV

8. Most hand-held bar code scanners are examples of which class of laser?

   (Circle your choice.)

   A. Class I
   B. Class II
   C. Class IIIa
   D. Class IIIb

9. Which classes of lasers **require** the word "Danger" on their Class Warning labels?

   (Circle your choice.)

   A. Classes I, II and IIa
   B. Classes II and IIa
   C. Classes IIIa and IIIb
   D. Class IIIb and IV

Answer	Additional Information
7. A	Class II lasers are considered safe if they are not viewed longer than one quarter of a second—the length of time of the eye's aversion response.
8. B	Most bar code scanners are Class II. Another example of Class II lasers are measuring devices.
9. D	All Class IIIb and IV lasers require the word "Danger" on their labels.

10. Certification of commercial laser products is the responsibility of which of the following?

(Circle your choice.)

A. The FDA
B. The laser user
C. The laser manufacturer
D. Company management

Answer	Additional Information
10. C	The laser manufacturer is responsible for the certification of laser products and devices.

➤ Topic 1.1 Summary

- Ordinary light has the following characteristics:
  1. Poly-chromatic
  2. Non-directional
  3. Incoherent
- Laser radiation has the following characteristics:
  1. Monochromatic
  2. Directional
  3. Coherent
- The three major components of a laser are:
  1. Lasing medium
  2. Excitation system
  3. Optical resonator
- The acronym LASER stands for "Light Amplification by Stimulated Emission of Radiation."
- The four major types of lasers based on the lasing medium are:
  1. Solid-state
  2. Semi-conductor
  3. Liquid
  4. Gas
- The four major laser classifications are:
  1. Class I
  2. Class II
  3. Class III
  4. Class IV
- The most common types of laser labels are:
  1. Certification Label
  2. Class Warning Label
  3. Aperture Label
  4. Protective Housing Label
- Certification of a laser is done by the manufacturer. It is the responsibility of the user to maintain a laser product according to the manufacturers instructions.

Review the material in Videotape Topic 1.1 for more detailed information on any of these subjects.

Topic 1.2
Laser Hazards

➤ Introduction

In this section you'll learn the basic physiology of the eyes and skin, the ways in which you can be exposed to laser radiation, and the kinds of damage that may result from laser radiation exposure.

➤ Learning Objectives

When you have completed this section, you should be able to do the following:

- Identify the major structures of the eye.
- Identify the type of damage that can occur to each major eye structure from hazardous laser radiation.
- Identify the major structures of the skin.
- Identify the three basic types of laser-beam exposure.
- Define the term MPE.

➤ Learning Resources

- Videotape Topic 1.2: Laser Hazards
- Workbook Topic 1.2 Exercise
- Topic Summary

➤ Directions for Proceeding

✓ *Complete the following steps in order. You may want to check off each step as you complete it.*

___ 1. Read the workbook introduction to Videotape Topic 1.2.

___ 2. Watch Videotape Topic 1.2.

___ 3. Complete Topic 1.2 Exercise.

___ 4. Read the Topic Summary in this Workbook.

Topic 1.2 Exercise
Laser Hazards

✓ *Directions: Check or circle your answer(s) to each question. When you complete the exercise, fold over the right side of the page to check your answers, then, turn the page to get more information about each question. Remember, some questions may have more than one answer.*

1. Which of the following is the transparent outer surface of the eye?

   (Circle your choice.)

   A. Retina
   B. Lens
   C. Cornea
   D. Fovea

2. Which one of the following eye structures is the region for clear and critical vision?

   (Circle your choice.)

   A. Lens
   B. Macula
   C. Cornea
   D. Photoreceptors

3. Which type of eye damage is most likely to occur if the lens is exposed to ultraviolet laser radiation?

   (Circle your choice.)

   A. Cataract
   B. Retinal burn
   C. Partial blindness
   D. Total blindness

Topic 1.2 Exercise
Laser Hazards

Answer	Additional Information
1. C	The transparent outer surface of the eye is the cornea.
2. B	The region for clear and critical vision is the macula.
3. A	If the lens is exposed to ultraviolet laser radiation, a cloudy or opaque area may appear called a cataract.

4. Which type of reflection is caused when a beam strikes a mirror-like surface?

   (Circle your choice.)

   A. Direct
   B. Intrabeam
   C. Diffuse
   D. Specular

5. Hazardous exposure to diffusely reflected laser radiation is most likely to occur from which class of laser?

   (Circle your choice.)

   A. Class II
   B. Class IIIa
   C. Class IIIb
   D. Class IV

6. Which one of the following does NOT determine the Maximum Permissible Exposure for a particular laser?

   (Circle your choice.)

   A. Laser classification
   B. Wavelength
   C. Exposure duration

Answer	Additional Information
4. D	The reflection of a beam from a mirror-like surface does not scatter. This fact, called specular reflection, means that the properties of the reflected beam can approach those of the incident or direct beam.
5. D	Hazardous exposure to diffusely reflected laser radiation usually does not occur unless the laser is a Class IV laser.
6. A	The Maximum Permissible Exposure for a laser depends upon its wavelength and the exposure duration. Laser classification does not determine the MPE.

➤ Topic 1.2 Summary

- The major structures of the eye are:
  1. Cornea
  2. Lens
  3. Retina
  4. Macula
  5. Fovea
  6. Optic Nerve
- The major eye structures may receive the following types of damage if exposed to laser radiation:

Eye Structure	Type of Damage
Cornea	Corneal Burn
Lens	Cataracts
Retina	Decreased Vision/Loss of Vision
Optic Nerve	Blindness

- The two main layers of the skin are the epidermis and the dermis. The epidermis contains the stratum corneum, pigment granules, and melanin. The dermis contains sweat glands, hair follicles, and blood vessels.
- The three types of laser-beam exposure are:
  1. Intrabeam
  2. Specular reflection
  3. Diffuse reflection
- The amount of laser radiation to which individuals may be safely exposed without hazardous effect or adverse biological change is called the Maximum Permissible Exposure level, or MPE.

Review the material in Videotape Topic 1.2 for more detailed information on any of these subjects.

Tape 2

2.1 Class II and Class IIIa Lasers
2.2 High Powered Lasers

Topic 2.1
Class II and Class IIIa Lasers

➤ Introduction

In this section you will learn about the major characteristics of Class II and Class IIIa lasers. This topic also includes information on the hazards associated with these two classes of lasers and the important safety precautions you should take while working with these lasers.

➤ Learning Objectives

When you have completed this section, you should be able to do the following:

- Identify the major characteristics of Class II lasers.
- Identify the major characteristics of Class IIIa lasers.
- Recognize the difference between a low-irradiance Class IIIa laser and a high-irradiance Class IIIa laser.
- Identify the types of hazards that can occur from exposure to laser radiation from Class II and Class IIIa lasers.
- Identify safety precautions appropriate for Class II and Class IIIa lasers.

➤ Learning Resources

- Videotape Topic 2.1: Class II and Class IIIa Lasers
- Workbook Topic 2.1 Exercise
- Topic Summary

➤ Directions for Proceeding

✓ *Complete the following steps in order. You may want to check off each step as you complete it.*

___ 1. Read the workbook introduction to Videotape Topic 2.1.

___ 2. Watch Videotape Topic 2.1.

___ 3. Complete Topic 2.1 Exercise.

___ 4. Read the Topic Summary in this Workbook.

Topic 2.1 Exercise
Class II and Class IIIa Lasers

✓ *Directions: Check or circle your answer(s) to each question. When you complete the exercise, fold over the right side of the page to check your answers, then, turn the page to get more information about each question. Remember, some questions may have more than one answer.*

1. Power emitted from a Class II laser does NOT exceed which of the following?

   (Circle your choice.)

   A. 1/2 milliwatt
   B. 1 milliwatt
   C. 5 milliwatts
   D. 10 milliwatts

2. High-Irradiance Class IIIa lasers have Class Warning labels described as which of the following?

   (Circle your choice.)

   A. Yellow and black "Caution"
   B. Red, black, and white "Caution"
   C. Red, black, and white "Danger"
   D. This type of laser does not need a warning label

3. What type of viewing hazard may occur if viewing of laser radiation is hazardous for exposures less than one quarter of a second?

   (Circle your choice.)

   A. Aversion response time
   B. An acute viewing hazard
   C. A critical viewing hazard
   D. A chronic viewing hazard

Topic 2.1 Exercise
Class II and Class IIIa Lasers

Answer	Additional Information
1. B	Class II lasers produce visible continuous wave beams and emit power of less than one milliwatt. These are all charge-generating objects and should be kept away from sensitive components.
2. C	High-irradiance Class IIIa lasers require a red, black, and white "Danger" label.
3. B	Viewing laser radiation for less than one quarter of a second is called an acute viewing hazard.

Topic 2.1 Exercise
Class II and Class IIIa Lasers

4. Protective eyewear may be necessary to provide protection from potentially hazardous exposure to the direct beam from which class of laser?

   (Circle your choice.)

   A. Class II

   B. Class IIa

   C. Low-Irradiance Class IIIa

   D. High-Irradiance Class IIIa

Answer	Additional Information
4. **D**	Eyewear may be necessary to protect you from the direct beam of high-irradiance Class IIIa Lasers.

➤ Topic 2.1 Summary

- Class II lasers produce visible, continuous wave (CW) beams. They emit power of less than 1 milliwatt. Class II lasers are used for chemical analysis, floor and ceiling installation, and other kinds of precision measurement and alignment.
- Class IIIa lasers emit visible beams with a power between 1 and 5 milliwatts. Class IIIa lasers are used for classroom applications, alignment, and precision measurement in machine tooling.
- The beam of a low-irradiance Class IIIa laser is *less* than 2.5 milliwatts per squared centimeter, which is safe for momentary viewing.
- The beam of a high-irradiance Class IIIa laser is *greater* than 2.5 milliwatts per squared centimeter. Even momentary exposure to its beam is not safe.
- Acute viewing is defined as viewing laser radiation for less than 1/4 of a second. You can view a Class II laser beam for less than 1/4 of a second and not be injured, therefore, it is not considered an acute viewing hazard.
- The opposite of acute viewing is chronic viewing. Viewing Class II lasers for longer than 1/4 of a second (chronic viewing) can be hazardous.
- A low-irradiance Class IIIa laser can be a potential hazard if you view its beam directly for more than 1/4 of a second.
- If you look directly into the beam of a high-irradiance Class IIIa laser, you may be subjected to an acute viewing hazard.

Review the material in Videotape Topic 2.1 for more detailed information on any of these subjects.

Topic 2.2
High-Powered Lasers

➤ Introduction

In this topic you will learn about the major characteristics of high-powered lasers. This topic also includes information on non-laser beam hazards, engineering and procedural control measures you should know before working with high-powered lasers and general information about how fiber optics are used with lasers.

➤ Learning Objectives

When you have completed this topic, you should be able to do the following:

- Identify the major characteristics of Class IIIb lasers.
- Identify the major characteristics of Class IV lasers.
- Define the term NHZ.
- Recognize chemical agent non-beam hazards.
- Recognize physical agent non-beam hazards.
- Identify engineering control measures.
- Identify procedural control measures.
- Identify the ways in which optical fibers are used with high-powered laser systems.

➤ Learning Resources

- Videotape Topic 2.2: High-Powered Lasers
- Workbook Topic 2.2 Exercise
- Topic Summary

➤ Directions for Proceeding

✓ *Complete the following steps in order. You may want to check off each step as you complete it.*

— 1. Read the workbook introduction to Videotape Topic 2.2.

— 2. Watch Videotape Topic 2.2.

— 3. Complete Topic 2.2 Exercise.

— 4. Read the Topic Summary in the Workbook.

Topic 2.2 Exercise
High-Powered Lasers

✓ *Directions: Check or circle your answer(s) to each question. When you complete the exercise, fold over the right side of the page to check your answers, then, turn the page to get more information about each question. Remember, some questions may have more than one answer.*

1. The maximum output from a Class IIIb continuous-wave, ultraviolet laser with a wavelength of 249 nanometers would have which of the following limits?

   (Circle your choice.)

   A. The same as an infrared laser
   B. 1/2 watt
   C. Less than 1/2 watt
   D. Greater than 1 watt

2. Which class would a diode laser emitting invisible, infrared radiation be?

   (Circle your choice.)

   A. Class II
   B. Class IIa
   C. Class IIIa
   D. Class IIIb

3. What does the Nominal Hazard Zone represent?

   (Circle your choice.)

   A. The focal point of a converging beam.
   B. The time it takes to reach safe exposure levels.
   C. The region within which the level of laser radiation exceeds the MPE.
   D. The crossover point from Class IV to Class IIIb levels of laser radiation.

Answer	Additional Information
1. C	Because of the increased potential hazard of ultraviolet radiation, the maximum power decreases for ultraviolet wavelengths that are less than 315 nanometers.
2. D	Because diode lasers emit invisible infrared radiation they are classified as IIIb.
3. C	The Nominal Hazard Zone defines the area in which levels of laser radiation exceed the Maximum Permissible Exposure.

4. Besides completing the required training, what else do you need to do when working with chemicals?

   (Circle your choice.)

   A. Review the Standard Operating Procedures.
   B. Follow the instructions in the Material Safety Data Sheet.
   C. Temporarily control the area.
   D. Post "Warning" signs.

5. Airborne contaminants are created by which one of the following activities?

   (Circle your choice.)

   A. Dyes dissolved in a solvent.
   B. Large amounts of inert buffer gases released into the air.
   C. A high-powered laser beam interacting with metal.
   D. All of the above.

6. Which one of the following is NOT a type of collateral radiation normally associated with laser output?

   (Circle your choice.)

   A. Laser Beam
   B. X-Radiation
   C. Radio frequency
   D. Ultraviolet

Answer	Additional Information
4. B	Be sure to read and follow all the instructions in the Material Safety Data Sheet for all the chemicals used with your lasers.
5. D	Airborne contaminants are created by many different laser-related activities.
6. A	X-radiation, Radio frequency, and Ultraviolet radiation are all types of collateral radiation.

Topic 2.2 Exercise
High-Powered Lasers

7. Which one of the following is a device intended to prevent access to hazardous laser radiation when an enclosure is opened?

   (Circle your choice.)

   A. Protective housing
   B. Warning system
   C. Interlock
   D. Beam stop

8. Which one of the following does NOT determine the optical density of an eyewear's filter?

   (Circle your choice.)

   A. The filter.
   B. The thickness of the filter.
   C. The color of the filter.
   D. The wavelength of the radiation to be filtered.

9. If you establish a temporary controlled area while servicing an embedded high-powered laser, what else must be present?

   (Circle your choice.)

   A. A warning system
   B. A "Notice" sign
   C. The Laser Safety Officer
   D. An emergency override switch

Answer	Additional Information
7. C	Devices called interlocks may help prevent access to hazardous laser radiation when enclosures are opened.
8. C	Optical density is determined by the filter, its thickness, and the wavelength of the radiation to be filtered.
9. B	You must post a "Notice" sign outside the controlled area to warn anyone in the area of the potential hazard.

10. A fiber optic system is considered to be which of the following when the fibers are connected at both ends?

    (Circle your choice.)

    A. "Partially enclosed system"

    B. "Partially controlled system"

    C. "Totally enclosed system"

    D. "Totally controlled system"

Answer	Additional Information
10. C	A fiber optic system in which the cables are connected at both ends is considered a "totally enclosed system."

➤ Topic 2.2 Summary

- Class IIIb lasers may be pulsed or continuous-wave and their radiation may be visible or invisible. Class IIIb continuous-wave lasers range in power to half a watt. Most diode lasers are Class IIIb because they emit invisible infrared radiation.
- Class IV lasers may be pulsed or continuous-wave, their radiation may be visible or invisible. They operate at powers greater than Class IIIb lasers (above half a watt).
- The Nominal Hazard Zone (NHZ) is the area in which the threat of potential overexposure to laser radiation exists.
- Chemical agent non-beam hazards include:
    1. Dyes
    2. Solvents
    3. Gases
    4. Airborne contaminants
- Physical agent non-beam hazards include:
    1. Electricity
    2. Collateral radiation
    3. Plasma radiation
    4. Fire
    5. Explosions
- Engineering control measures are designed into the laser device by the manufacturer or are built into the workplace. They include such measures as:
    1. Protective housings
    2. Beam controls
    3. Emission indicators
    4. Viewing systems
- Procedural control measures are policies that must be followed to avoid laser hazards. They include such measures as:
    1. Standard Operating Procedures
    2. Eye protection
    3. Skin protection
    4. Alignment procedures
- In the lab, optical fibers are used to develop new communication systems, often between work sites. In industry, optical fibers are often part of systems that deliver high-powered laser beams to materials processing such as welding, drilling, or cutting.

Review the material in Videotape Topic 2.2 for more detailed information on any of these subjects.

Tape 3

3.1 High Powered Lasers in Manufacturing

Topic 3.1
High-Powered Lasers in Manufacturing

➤ Introduction

In this section you'll learn about high-powered lasers in manufacturing and how to assure their safe use.

➤ Learning Objectives

When you have completed this topic, you should be able to do the following:

- Identify the types of lasers used in manufacturing.
- Identify some of the most common uses of high-powered lasers in manufacturing.
- Recognize some of the common hazards found in manufacturing.
- Identify engineering and procedural control measures used with lasers in manufacturing.

➤ Learning Resources

- Videotape Topic 3.1: High-Powered Lasers in Manufacturing
- Workbook Topic 3.1 Exercise
- Topic Summary

➤ Directions for Proceeding

✓ *Complete the following steps in order. You may want to check off each step as you complete it.*

___ 1. Read the workbook introduction to Videotape Topic 3.1.

___ 2. Watch Videotape Topic 3.1.

___ 3. Complete Topic 3.1 Exercise.

___ 4. Read the Topic Summary in this Workbook.

Topic 3.1 Exercise
High-Powered Lasers in Manufacturing

✓ *Directions: Check or circle your answer(s) to each question. When you complete the exercise, fold over the right side of the page to check your answers, then, turn the page to get more information about each question. Remember, some questions may have more than one answer.*

1. A sensor card does which of the following?

   (Circle your choice.)

   A. Converges the laser beam.
   B. Re-directs the laser beam.
   C. Partially absorbs the laser beam.
   D. Produces a visible spot at the location of the beam.

2. What is the best way to control airborne contaminants?

   (Circle your choice.)

   A. Set up a temporary controlled area.
   B. Use a flame retardant curtain.
   C. Use an exhaust ventilation system.
   D. Do not use target materials.

3. To help ensure that you are not exposed to high voltage when the power is off, power supplies should be equipped with which of the following?

   (Circle your choice.)

   A. De-energized power supply
   B. Grounding strap
   C. Beam shutter
   D. Insulated gloves

Topic 3.1 Exercise
High-Powered Lasers in Manufacturing

Answer		Additional Information
1.	D	A sensor card produces a visible spot at the location of the beam which can be seen through protective eyewear.
2.	C	The best way to control airborne contaminants is to use an exhaust ventilation system.
3.	B	A grounding strap to the capacitor will help ensure that you are not exposed to high voltage.

4. What is one of the most important pieces of information included in the Standard Operating Procedures for a laser in manufacturing?

   (Circle your choice.)

   A. Identification of potential hazards.

   B. The name of the Laser Safety Officer.

   C. The name of the laser manufacturer.

   D. Medical requirements.

5. If you must enter the Nominal Hazard Zone, what is the best thing you can do to protect yourself from potential hazardous exposure?

   (Circle your choice.)

   A. Notify the Laser Safety Officer.

   B. Activate the warning system.

   C. Wear protective eyewear.

   D. Stand near the temporary barrier.

Answer	Additional Information
4. A	Standard Operating Procedures should specify all potential hazards associated with the laser.
5. C	If you must enter the Nominal Hazard zone, protective eyewear can protect you from potential hazardous exposure.

➤ Topic 3.1 Summary

- The most common types of high-powered lasers used in manufacturing are CO_2 and neodymium–YAG lasers.
- High-powered lasers are most often used for materials processing such as welding, drilling, cutting, scribing, and engraving.
- Some of the most common hazards found in manufacturing are:
    1. Open beams due to removal of protective housings.
    2. Surfaces, such as hand tools, may create specular reflections.
    3. Improperly restored system components.
    4. A cluttered work environment.
    5. Airborne contaminants from materials processing.
    6. Broken equipment and worn labels.
    7. High voltage.
- Control measures that should be used in a manufacturing environment include:
    1. Protective housings and interlocks.
    2. Warning systems.
    3. Protective eyewear.
    4. Barriers or curtains.
    5. Danger signs.
    6. Reading the Standard Operating Procedures.

Review the material in Videotape Topic 3.1 for more detailed information on any of these subjects.

Tape 4

4.1 High Powered Lasers in the Laboratory

Topic 4.1
High-Powered Lasers in the Laboratory

➤ Introduction

In this section you will learn about high-powered lasers in the laboratory and how to assure their safe use.

➤ Learning Objectives

When you have completed this topic, you should be able to do the following:

- Identify the types of lasers used in the laboratory.
- Identify some of the most common uses of high-powered lasers in the laboratory.
- Recognize some of the common hazards found in the laboratory.
- Identify engineering and procedural control measures used with lasers in the laboratory.

➤ Learning Resources

- Videotape Topic 4.1: High-Powered Lasers in the Laboratory
- Workbook Topic 4.1 Exercise
- Topic Summary

➤ Directions for Proceeding

✓ *Complete the following steps in order. You may want to check off each step as you complete it.*

___ 1. Read the workbook introduction to Videotape Topic 4.1.

___ 2. Watch Videotape Topic 4.1.

___ 3. Complete Topic 4.1 Exercise

___ 4. Read the Topic Summary in this Workbook.

Topic 4.1 Exercise
High-Powered Lasers in the Laboratory

✓ *Directions: Check or circle your answer(s) to each question. When you complete the exercise, fold over the right side of the page to check your answers, then, turn the page to get more information about each question. Remember, some questions may have more than one answer.*

1. A sensor card does which of the following?

   (Circle your choice.)

   A. Converges the laser beam.

   B. Re-directs the laser beam.

   C. Partially absorbs the laser beam.

   D. Produces a visible spot at the location of the beam.

2. When enclosure of all exposed wavelengths is not possible, what is the best way to protect yourself when working with multiple wavelengths?

   (Circle your choice.)

   A. Use only wavelengths that are invisible.

   B. Label all access points.

   C. Wear eyewear with orange filters.

   D. Wear eyewear appropriate for all wavelengths.

3. What is the best way to control airborne contaminants?

   (Circle your choice.)

   A. Set up a temporary controlled area.

   B. Use a flame retardant curtain.

   C. Use an exhaust ventilation system.

   D. Do not use target materials.

Topic 4.1 Exercise
High-Powered Lasers In the Laboratory

Answer	Additional Information
1. D	A sensor card produces a visible spot at the location of the beam which can be seen through protective eyewear.
2. D	If you cannot enclose all exposed beams, the best way to protect yourself is to wear eyewear that protects you from *all* of the wavelengths.
3. C	The best way to control airborne contaminants is to use an exhaust ventilation system.

4. What important pieces of information should be included in the Standard Operating Procedures for a laser in the laboratory?

   (Circle your choice.)

   A. Identification of hazards and safe alignment procedures.

   B. The name of the Laser Safety Officer and the manufacturer.

   C. Operating and emergency procedures.

   D. Training and medical requirements.

5. If you must enter the Nominal Hazard Zone, what is the best thing you can do to protect yourself from potential hazardous exposure?

   (Circle your choice.)

   A. Notify the Laser Safety Officer.

   B. Activate the warning system.

   C. Wear protective eyewear.

   D. Stand near the temporary barrier.

Answer	Additional Information
4. A	The Standard Operating Procedures should include identification of all potential hazards and, in particular, should specify safe alignment procedures.
5. C	Protective eyewear can protect you from potential hazardous exposure if you must enter the Nominal Hazard Zone (NHZ).

➤ Topic 4.1 Summary

- Helium-neon, argon, excimer, dye, and neodymium–YAG are the types of lasers most often found the laboratory.
- In addition to their experimental applications, lasers are used in research labs for basic studies in optical physics and photochemistry.
- Some of the most common hazards found in the laboratory are:
    1. Open beams that are not totally enclosed.
    2. Open beams accessed during alignment procedures.
    3. Multiple wavelengths.
    4. Unprotected viewing systems.
    5. Crowded conditions and poor housekeeping.
    6. Exposure to collateral radiation.
    7. Exposure to chemical agents.
- Control measures that should be used in a laboratory environment include:
    1. Protective housings and interlocks.
    2. Warning systems.
    3. Protective eyewear.
    4. Barriers or curtains.
    5. Safe alignment procedures.
    6. Danger signs.
    7. Reading the Standard Operating Procedures.

Review the material in Videotape Topic 4.1 for more detailed information on any of these subjects.

Tape 5

5.1 Servicing High Powered Lasers
5.2 Servicing Optical Fiber Communication Systems

Topic 5.1
Servicing High-Powered Lasers

➤ Introduction

In this section you will learn how to identify and avoid the hazards of servicing high-powered lasers.

➤ Learning Objectives

When you have completed this topic, you should be able to do the following:

- Recognize some of the common hazards found while servicing laser systems.
- Identify engineering and procedural control measures used when servicing lasers.

➤ Learning Resources

- Videotape Topic 5.1: Servicing High-Powered Lasers
- Workbook Topic 5.1 Exercise
- Topic Summary

➤ Directions for Proceeding

✓ *Complete the following steps in order. You may want to check off each step as you complete it.*

___ 1. Read the workbook introduction to Videotape Topic 5.1.

___ 2. Watch Videotape Topic 5.1.

___ 3. Complete Topic 5.1 Exercise.

___ 4. Read the Topic Summary in the Workbook.

Topic 5.1 Exercise
Servicing High-Powered Lasers

✓ Directions: Check or circle your answer(s) to each question. When you complete the exercise, fold over the right side of the page to check your answers, then, turn the page to get more information about each question. Remember, some questions may have more than one answer.

1. Which of the following is best to use to prevent errant beams from exiting the area?
   A. "Notice" sign.
   B. Curtain.
   C. Viewing instrument.
   D. Flashing light.

2. What is the last task you should perform after you have finished servicing the laser?
   A. Put your tools away.
   B. Inform the Laser Safety Officer that you are finished.
   C. Reactivate all safety features.
   D. Activate the laser to ensure that it works properly.

3. What is one of the best safety precautions you can take when testing high voltage systems?
   A. Make sure you know CPR.
   B. Make sure the system has been de-energized for at least 2 hours.
   C. Make sure there is at least one other person nearby.
   D. Do not allow anyone in the area.

Topic 5.1 Exercise
Servicing High-Powered Lasers

Answer	Additional Information
1. B	Use a laser-protective curtain to prevent beams from exiting the work area.
2. C	After servicing a laser, restore all safety features. If you do not, you may risk overexposing subsequent operators.
3. C	Have at least one person working near you who can administer CPR or summon help when servicing high voltage systems.

Topic 5.1 Exercise
Servicing High-Powered Lasers

4. What should you do if you need to leave the area while you are still servicing the laser?
   A. Post a temporary "Warning" sign.
   B. Place a temporary curtain over the laser.
   C. Take the master key with you.
   D. Lock the door to the work area.

5. What should you do if you need to service a laser with which you are unfamiliar?
   A. Talk to the Laser Safety Officer.
   B. Talk to the technicians who operate the laser.
   C. Make sure that the laser is certified.
   D. Read the service manual.

Answer	Additional Information
4. C	If you need to leave equipment while you are still servicing it, take the master key with you.
5. D	Read the service manual when you have to service equipment with which you are not familiar.

➤ Topic 5.1 Summary

Some of the potential hazards encountered while servicing lasers include:

- A rushed and stressful environment.
- Open beams as a result of removed protective housings and defeated interlocks.
- Unauthorized personnel within a temporary laser controlled area.
- Improperly restored system components.
- Malfunctioning equipment.
- High voltage.

Control measures while servicing lasers should include:

- Use only the proper defeat mechanisms.
- Use warning systems or temporary barriers.
- Wear protective eyewear.
- Post "Notice" signs at the entrance to a temporary controlled area.
- Review all safety procedures before working on the system.
- Follow proper lockout/tagout procedures when working near a power source.
- Discharge and ground all high energy capacitors.
- Read the service manual.
- Read all labels on the laser system.
- If you need to leave the equipment while you are still servicing it, take the master key with you.
- Report any service condition that may be hazardous to the Laser Safety Officer (LSO).

Review the material in Videotape Topic 5.1 for more detailed information on any of these subjects.

Topic 5.2
Servicing Optical Fiber Communication Systems

➤ Introduction

In this topic you will learn how to identify and avoid the hazards of servicing Optical Fiber Communication Systems (OFCS).

➤ Learning Objectives

When you have completed this topic, you should be able to do the following:

- Identify the major characteristics of Optical Fiber Communication Systems.
- Define the term MPI.
- Identify the characteristics of the four Service Group Classifications.
- Recognize some of the common hazards from laser radiation found while servicing Optical Fiber Communication Systems.
- Recognize some of the common hazards from non-laser radiation found while servicing Optical Fiber Communication Systems.
- Identify engineering and procedural control measures used when servicing Optical Fiber Communication Systems.
- Identify safe work practices that should be used when working with Optical Fiber Communication Systems.

➤ Learning Resources

- Videotape Topic 5.2: Servicing Optical Fiber Communication Systems
- Workbook Topic 5.2 Exercise
- Topic Summary

➤ Directions for Proceeding

✓ *Complete the following steps in order. You may want to check off each step as youcomplete it.*

___ 1. Read the workbook introduction to Videotape Topic 5.2.

___ 2. Watch Videotape Topic 5.2.

___ 3. Complete Topic 5.2 Exercise.

___ 4. Read the Topic Summary in the Workbook.

Topic 5.2 Exercise
Servicing Optical Fiber Communication Systems

✓ *Directions: Check or circle your answer to each question. When you complete the exercise, fold over the right side of the page to check your answers, then, turn the page to get more information about each question. Remember, some questions may have more than one answer.*

1. Which one of the following is the most common wavelength range used with the source of OFCS signals?

   A. Visible radiation

   B. Invisible radiation in the near infrared

   C. Invisible radiation in the far infrared

   D. Invisible radiation in the ultraviolet

2. What happens if a fiber end is broken or irregular?

   A. Signals travel a greater distance

   B. Signals travel a shorter distance

   C. The power is decreased

   D. Light is reflected or scattered

3. Which one of the following factors is NOT considered when determining the Service Group Classification scheme?

   A. Normal operating conditions

   B. Manufacturing conditions

   C. Servicing conditions

   D. Installation conditions

Answer	Additional Information
1. B	The sources of OFCS signals are almost always invisible radiation in the near infrared.
2. D	If fiber ends are broken or irregular, they will reflect or scatter the light and cause signal loss.
3. A	The ANSI classification scheme is based on Service Groups because there is only a potential hazard during manufacturing, installation, or servicing.

4. SG2 systems produce which of the following laser radiation wavelengths?

   A. 300 to 400 nanometers

   B. 400 to 700 nanometers

   C. 700 to 1400 nanometers

   D. 1400 to 3000 nanometers

5. Which system is considered potentially hazardous when viewed with a microscope or eye-loupe?

   A. SG1

   B. SG2

   C. SG3a

   D. SG3b

6. Which of the following is one of the most common causes for potential OFCS hazards that is not directly related to laser radiation?

   A. High voltage

   B. Collateral radiation

   C. Glass shards

   D. Airborne contaminants

Answer	Additional Information
4. B	SG2 systems produce visible laser radiation in the region of 400 to 700 nanometers.
5. C	SG3a systems are considered potentially hazardous when viewed with a microscope or an eye loupe.
6. C	Glass shards result from cleaving and stripping optical fibers and are not directly related to the operation of lasers.

7. What is the best control measure to use in an uncontrolled area when you have not determined the Service Group classification of the system you are servicing?

   A. Use an optical viewing aid

   B. Use safety connectors

   C. Read all of the labels

   D. Read the service manual

8. You should define a controlled area around an energized SG3b system when the Critical Viewing Distance exceeds how many centimeters?

   A. 10

   B. 50

   C. 100

   D. 500

9. Which of the following is best to use to collect shards when stripping fibers?

   A. Cotton swab

   B. Masking tape

   C. Gloves

   D. Small brush

Answer	Additional Information
7. B	Use safety connectors when you are in an uncontrolled area and have not determined the Service Group Classification of the system.
8. C	Define a controlled area around an energized SG3b system whenever the distance from the end of the fiber to the area where you are safe from exposure exceeds 100 centimeters.
9. B	When stripping or cleaving fibers use masking tape to collect the glass shards.

10. Which of the following should you read if you need to use chemicals during servicing?
    A. Standard Operating Procedures
    B. Service Manual
    C. ANSI Z136.2
    D. Material Safety Data Sheet

Answer	Additional Information
10. D	When using chemicals, follow the manufacturer's recommendations contained in the Material Safety Data Sheet (MSDS).

➤ Topic 5.2 Summary

- Optical Fiber Communication Systems (OFCS) transmit laser radiation through optical fibers.
- The sources of OFCS signals are either light emitting diodes or laser diodes.
- OFCS signals can travel great distances without significant loss of laser radiation.
- The term MPI, or Maximum Permissible Irradiance, is the level above which continued exposure presents a potential hazard.
- There are four major Service Group Classifications:
  1. SG1
  2. SG2
  3. SG3a
  4. SG3b
- *SG1* cannot emit potentially hazardous radiation in the visible and near-infrared region of 400 to 1400 nanometers for 100 seconds.
- For the duration of 100 seconds, *SG2* systems produce visible laser radiation in the region of 400 to 700 nanometers at levels greater than those produced by SG1 systems.
- *SG3a* systems produce laser radiation in the visible wavelength region of 400 to 700 nanometers at levels greater than SG2 systems for one-quarter of a second.
- *SG3b* systems produce light in the visible, near-infrared, or infrared that emits accessible radiation greater than SG3a but not greater than 500 milliwatts.
- OFCS hazards from laser radiation include:
  1. Looking into a disconnected, energized SG3b system with or without the aid of an optical viewing device.
  2. Looking into a disconnected, energized SG3a system with the aid of an optical viewing device.
  3. Using test equipment with an unfiltered optical viewing aid.
- OFCS hazards from non-laser radiation include:
  1. Using photocuring devices that can produce hazardous levels of UV radiation.
  2. Small lengths or particles of fiber produced during splicing operations.
  3. Chemicals and solvents used for stripping fibers and cleaning and splicing fiber elements.
- Control measures for OFCS:
  1. Use safety connectors in uncontrolled areas.
  2. Use the labeling specified in ANSI Z136.2.
  3. Label the patch panel, patch cords, and outlet.
  4. Only trained personnel should install or service SG3b systems.

5. Define a controlled area around an SG3b system.
6. Make sure viewing optics have the appropriate safety filter.

- Safe work practices for OFCS:
  1. Follow lock out/tag out procedures.
  2. Wear protective eyewear.
  3. Read the Service Manual.
  4. If you do not know, assume the system is SG3b.
  5. When stripping or cleaving fibers, wear protective eyewear and use masking tape to dispose of the particles.
  6. When using chemicals, follow the recommendations contained in the Material Safety Data Sheet (MSDS).

Review the material in Videotape Topic 5.2 for more detailed information on any of these subjects.

APPENDICES

A: Glossary

B: Bibliography

APPENDIX A
Glossary

Acute Viewing Viewing a laser beam for less than one-quarter of a second.

Argon Laser A type of gas laser used in scientific laboratories, laser-light shows, and in the medical environment. Generally, two common wavelengths, or colors—green and/or blue—are associated with its operation.

Atom The smallest part of an element that can take part in a chemical reaction; composed of electrons, protons, and neutrons.

Aversion Response Natural (innate) behavior that occurs when the eye is exposed to a source of bright light, such as a laser beam, flashlight, or headlamp. Examples of aversion response reactions include blinking, turning the head, raising the hand, etc.

Carbon Dioxide Laser A type of gas laser that produces invisible infrared radiation. Carbon dioxide lasers are used in industrial material processing and in the health-care environment.

Cataract A change in the naturally transparent nature of the lens of the eye that renders it opaque to light.

Chronic Viewing Viewing a laser beam for longer than one-quarter of a second.

Class I Lasers Lasers that are considered safe during normal operation.

Class IIa Lasers Very low-powered lasers that are safe if the visible beam is not viewed for longer than 1000 seconds.

Class II Lasers Low-powered lasers that produce visible beams that are safe to view for the human aversion response time of one-quarter of a second.

Class IIIa Lasers Low-to-moderate powered lasers with visible beams that are further sub-divided into low-irradiance and high-irradiance Class IIIa lasers. Low-irradiance Class IIIa lasers are safe to view for the human aversion response time of one-quarter of a second if not viewed with an optical instrument such as a binocular. The beams from high-irradiance Class IIIa lasers are not safe for momentary viewing.

Class IIIb Lasers Moderate to high powered lasers that may have visible or invisible beams. They are potential eye hazards when viewing the direct or specularly reflected beam.

Class IV Lasers High-powered lasers with visible or invisible beams. They are a potential health hazard to the eyes and skin under all conditions where exposure exceeds the MPE. They are also a potential fire hazard.

Coherent Radiation A characteristic of laser radiation which means that the waves are in step.

Collateral Radiation Non-laser radiation that is produced by the normal operation of a laser. The types of radiation that may be produced include x-radiation, ultraviolet, visible, radio frequency, and extremely low frequency (ELF).

Continuous Wave (CW) Lasers that are characterized by continuous operation, that is, lasers that are not pulsed.

Controlled Area An area in which occupancy is subject to control and supervision to achieve radiation protection.

Cornea The outer, transparent covering of the eye that interacts with the environment. It is composed of living cells that change the direction of incoming light. Subject to damage from some ultraviolet and infrared radiation.

Critical Viewing Distance The distance from the end of an optical fiber to the place where irradiance falls below the applicable MPI (Maximum Permissible Irradiance).

Dermis A principal layer of the skin that resides beneath the epidermis. The dermis is composed of living cells and contains many important structures including sweat glands, hair cells, and blood vessels.

Divergence The angular spread of electromagnetic radiation with increasing distance from its source. Laser beams are characterized by small angles of divergence.

Dye Laser A type of liquid laser which has the property of being adjustable, or tunable, regarding the wavelength of light emitted. This is accomplished by the selection of the dye powder, which is dissolved in a solvent.

Electromagnetic Energy Energy propagated by vibrating transverse electric and magnetic fields.

ELF Acronym for extremely low frequency, an order of magnitude band designation usually applied to the part of the electromagnetic spectrum between 30 and 300 MHz.

Energy The ability to do work. The unit of measurement is the joule (J).

Epidermis The outer four layers of the skin that provide the body's main barrier to external chemical and physical agents.

Excimer Laser A type of gas laser. The lasing medium is usually composed of toxic and corrosive halogen gases such as fluorine or hydrogen chloride. Used in the laboratory, health-care environment, and for material processing.

Excitation A physical process where electrons absorb energy that may be emitted at a later time. In the lasing process, excitation is followed by de-excitation and the energy is emitted as photons of laser light.

Excitation System The system component that "pumps" energy into the lasing medium, usually in the form of light or electrical energy.

Eye The sensory organ in the body that responds to light. For the purpose of this course, four main structures of the eye are at risk of laser-radiation-induced damage: cornea, lens, retina and optical nerve.

Fovea A sub-structure of the retina that resembles a pit or dimple and is located in the macula. It is the center for clear and critical vision and is used for reading, to discriminate objects, and to discern color.

Helium-Neon Laser A type of gas laser which uses helium and neon as the lasing medium. These are used in supermarket scanning systems, hand-held barcode scanners and in the construction industry. Although helium-neon lasers may emit a number of wavelengths, or colors, those most often used in the public domain have a red beam.

Incoherent Radiation A characteristic of ordinary light sources such as a light bulb, where the waves are out of step.

Infrared Imaging Scope A hand-held viewing instrument that allows you to view the reflection of an infrared beam through protective eyewear.

Infrared Radiation Invisible electromagnetic radiation that produces the sensation of heat when absorbed by the body. It occupies that part of the electromagnetic spectrum with wavelengths between 700 nanometers and 1 millimeter.

Interlock Typically a switch that, when activated, will interrupt the normal operation of the laser by closing a shutter or de-energizing the system. Interlocks may be included as a control measure for the protective housing of the laser system by the manufacturer, or may be built into the laser environment by the user. Interlocks may be intended to be defeated by an authorized user (defeatable interlocks), or they may be non-defeatable.

Irradiance A quantity used to describe the intensity of a laser beam. It is the power on a given cross-sectional area of a surface, usually in watts per square centimeter (W/cm^2) for laser radiation.

Laser Acronym for Light Amplification by Stimulated Emission of Radiation, which describes the physical process by which laser light is produced.

Laser Classification A scheme to allow the logical categorization of the potential hazard posed by a laser as a function of its power and its wavelength. Classification schemes are created by the U.S. Food and Drug Administration and by the Z136.1 Committee of the American National Standards Institute. The present federal classification scheme, from lowest to highest hazard/power: Class I, Class IIa, Class II, Class IIIa, Class IIIb, and Class IV.

Laser-Generated Air Contaminants (LGAC) Airborne contaminants that are created when the beam from a high-powered laser interacts with some material, such as plastics, composites, or metals.

Laser Safety Officer (LSO) An individual with the knowledge and authority to monitor and effect the control of laser hazards.

Laser Temporary Controlled Area An area temporarily established to serve a laser system; occupancy is subject to control and supervision for the purpose of radiation protection.

Lasing Medium The system component that absorbs energy from the excitation system; the medium may be a gas, liquid, or solid, or a type of solid called a semi-conductor.

Lens An interior structure of the eye that serves to bring light to a focus on the retina of the eye. Subject to damage by some ultraviolet and infrared wavelengths.

Light In this course, light includes ultraviolet, visible, and infrared radiation.

Macula A pigmented area of the retina that contains the fovea.

Melanin Pigment that gives skin its brownish color.

Micrometer A unit of length that is used to describe the wavelength of light equal to 1 millionth of a meter, or about 1/25,400 of an inch.

Monochromatic Composed of one color. When applied to laser radiation, it means that there is only one wavelength of light.

MPE The Maximum Permissible Exposure values are exposure limits, safe values of exposure to laser radiation, recommended in the American National Standards Institute publication *For the Safe Use of Lasers,* ANSI Z136.1-1992.

MPI The Maximum Permissible Irradiance values are exposure limits for laser or LED (light-emitting diode) radiation

associated with optical fiber communication systems (OFCS).

Nanometer A unit of length that is used to describe the wavelength of light. It is equal to 1 billionth of a meter, or about 1/25,400,000 of an inch.

Nominal Hazard Zone (NHZ) The space within which the level of laser radiation exceeds the safe level, the MPE.

Non-Beam Hazards Potential hazards that deal with agents other than the direct or scattered laser beam. These include chemical agents and physical agents. Chemical agents consist of chemicals used as the lasing media or those generated from the interaction of the laser beam with matter. Physical agents include electricity, plasma radiation, collateral radiation, noise, and others.

Optical Density A measure of the ability of a filter to attenuate laser light. The larger the number of the optical density, the greater the attenuation. For example, an optical density of 1 means an attenuation of 10 times, while 2 means 100 times.

Optical Fiber Communication Systems (OFCS) Communication systems utilizing laser diodes or light-emitting diodes (LEDs) and optical fibers.

Optical Resonator Two parallel mirrors located on either side of the optical axis of the lasing medium. One mirror is fully reflective at the laser wavelength(s), while the other is partially transparent. The mirrors reflect laser light within the resonator until a threshold is reached, allowing laser light to be transmitted through the partially transparent mirror.

Overexposure Exposure to laser radiation above the applicable MPE, that is, above the safe level.

Phase The stage in a cycle that a wave has reached in space and time.

Photon The smallest element or particle of electromagnetic energy.

Photosensitization Reaction of the skin to ultraviolet radiation plus a chemical substance. The chemical may be any of a number of substances including an ingredient in a medicine, cologne, or cosmetic.

Plasma Radiation Radiation generated from the interaction of laser radiation with metals. For the most part this includes ultraviolet and visible radiation. Although many visible wavelengths may be generated, the blue wavelengths are of greatest concern because of their greater ability to produce photochemical damage to the retina.

Polychromatic Composed of many colors; usually applied to incoherent sources of light, such as that emitted from a light bulb.

Power The rate of time at which energy is transmitted or used by a system; also, the rate at which work is done. The unit of measurement is the watt (W).

Radio-Frequency Fields Electromagnetic energy with frequencies between 300 MHz and 3 kHz, in this course.

Reflection The process by which electromagnetic energy, incident at a boundary between two materials, is re-directed back into the initial media. If the reflective surface scatters the beam it is called a diffuse reflection. If it does not, and the beam is unchanged, it is a specular reflection.

Refraction When electromagnetic energy is incident on the boundary between two media with different dielectric characteristics, its direction is changed, often referred to as bending.

Retina A structure of the eye that is an extension of the nervous system. The retina contains two light receptors. One type, located in the macula and

found most densely in the fovea, is responsible for clear and critical vision, that is reading and color vision.

Scanning The process through which a laser beam is spread out in space; it has the effect of reducing irradiance. Scanning is usually applied to bar-code reading applications, such as those found in supermarkets.

Sensor Cards Hand-held cards that are treated with phosphors so that they respond to invisible wavelengths by re-radiation or fluorescence at visible wavelengths. Often used as an aid in the alignment of invisible beams.

Skin The external covering of the body that is composed of two layers: the epidermis and the dermis.

Standard Operating Procedure (SOP) A procedural control measure that involves written detailed safety and operating procedures. SOPs are required by ANSI Z136.1 for operations where there is access to Class-IV levels of laser radiation. They are recommended for Class-IIIb operations.

Stratum Corneum The outermost layer of the epidermis that is in contact with the environment.

Ultraviolet Radiation Invisible electromagnetic radiation that has wavelengths between 100 and 400 nanometers. Ultraviolet radiation is associated with a number of diseases including cataracts, skin cancer, skin aging, and photosensitivity.

Visible Light Part of the electromagnetic spectrum between 400 and 700 nanometers, which is composed of the following colors: red, orange, yellow, green, blue, indigo, and violet.

Wavelength The distance that a wave travels during the time it takes to vibrate one complete cycle.

X-Radiation High energy electromagnetic radiation that may be produced by the rapid deceleration of electrons that are moving under the influence of high voltage.

APPENDIX B
Bibliography

These publications will provide you with additional information on laser safety:

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