Bioenvironmental Engineering Site Assessment I

Unit 11: Non-ionizing Radiation, Laser Hazards

Unit Description: For this unit, you will be stationed at Jillsong Base in San Antonio, TX. During your assignment, you'll review the fundamentals of lasers and identify and analyze laser hazards in the Air Force. When you're done, you'll be able to describe the factors BE should be concerned with when evaluating laser hazards and recommending appropriate controls.

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Lesson 1: Laser Fundamentals

Lesson Description

In this lesson, your BE shop will host a shop training about lasers in the Air Force. Upon completion of this lesson, you will be able to describe the fundamentals of lasers.

Lesson Overview (Page 1 of 8)

Lasers are a form of non-ionizing radiation that travels in a small, tight beam with minimal spreading. These characteristics allow lasers to be employed for a variety of purposes.

While preparing for the workshop, you will:

- Describe the operating principles of lasers.
- Recall components of lasers.
- List sources and uses of lasers in the Air Force.
- Recognize parameters required to classify a laser system.

Audio Script

NCOIC: Our shop will be hosting a workshop Friday afternoon. We're going to be discussing lasers commonly encountered by BE in the Air Force.

I'd like you to lead the workshop because I know you've had some experience with lasers at the labs on base. I have the notes from last year's workshop if you'd like to review those.

Scenario Challenge Point (Page 2 of 8)

To prepare for the workshop, you decide to create several visual aids to help describe the operating principles of lasers. Which one of the following statements is the correct definition of a laser?

A Luminescent apparatus for stimulating energy and rays.

B Light amplification by stimulated emission of radiation.

C Luminosity accelerated by simultaneous energy release.

D Lighting amplified by supplied energy and radiance.

Operating Principles of Lasers (Page 2a of 8)

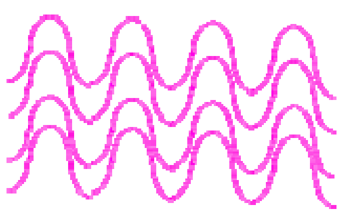
One form of radiation energy often overlooked in health risk assessments is laser hazards. The term laser stands for:

Light Amplification by **Stimulated Emission** of **Radiation**

Laser light is a form of concentrated energy that, with sufficient power and equipment design, can cut through any material. It travels in a small, tight beam with minimal spreading. These qualities have resulted in lasers being employed in diverse fields, ranging from military-specific uses to consumer products.

Light

A laser emits coherent light which occurs when the electromagnetic waves maintain a fixed phase relationship over a period of time and where the phase relationship remains constant for various points that are vertical to the direction of emission. In other words, the energy waves are aligned with one another.



Coherent Light

Incoherent Light

Amplification

The intensity of light produced from a laser is determined by how the light is amplified. This amplification process is based on the design characteristics of the laser.

Stimulated Emission

Stimulated emission of light occurs when the production of light is used to generate even more light. This occurs through a process where a photon interacts with matter and causes the matter to lose energy, resulting in the creation of another photon.

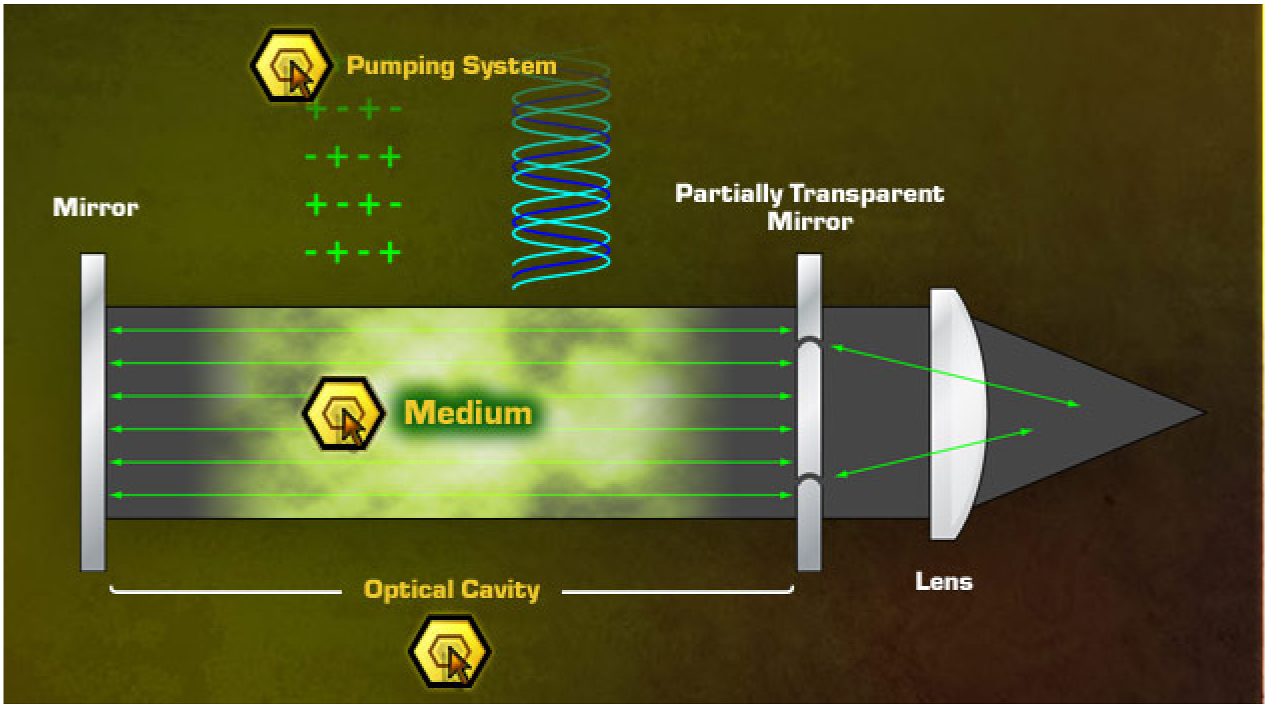
Radiation

The light produced by a laser is in the form of electromagnetic radiation similar to radio waves or x-rays. Laser radiation occurs in the UV, visible, and infrared range of the electromagnetic spectrum between 180 nm and 1 mm.

The placement on the spectrum determines the strength, color, and visibility of the laser, as well as appropriate applications.

Components of Lasers (Page 3 of 8)

All lasers have three basic components in common. These components are the pumping system, the medium, and the optical cavity.



Pumping System

The pumping system is the means of getting energy into the medium to excite the electrons. The primary function of the pumping system is to create a situation where there are more excited electrons giving off photon energy than there are electrons in a normal state.

Pumping systems can consist of electric current systems, chemical reaction systems, or other lasers.

Medium

The medium is considered the fundamental component of a laser system because it is the source of the laser photon energy. The medium is made up of atoms or molecules of a specific material which have useful characteristics when its electrons are excited by a pumping system. There are several types of mediums commonly used for lasers.

- Gas (i.e., Argon, helium, carbon dioxide)
- Solid State (i.e, ruby, NdYAG)
- Diode (i.e, gallium arsenide, lead sulfide)
- Excimer (i.e., ArF, XeCl, XeF)
- Dye (i.e., Rhodamine 6G)

Optical Cavity

The optical cavity is the component that houses the laser. This component acts like a resonant feedback system that focuses and amplifies photon energy in a laser beam.

The optical cavity has reflective surfaces, usually highly polished mirrors, at each end. One surface is approximately 99% reflective while the other is considerably less, usually approximately 65%. The photons travel back and forth between the mirrors until they reach a high enough intensity to pass through the less reflective mirror, creating a laser beam.

Appraisal (Page 4 of 8)

Match each component of a laser system with its function by marking the appropriate block in the table.

Description	Pumping System	Medium	Optical Cavity
This component is the source of the laser photon energy.			
This component focuses and amplifies photon energy in a laser beam.			
This component excites the electrons so they give off photon energy.			

Scenario Challenge Point (Page 5 of 8)

To help the participants in your workshop identify where they may find laser sources at their base, as one of your visual aids, you decide to list several examples of lasers commonly found in the Air Force.

Match each type of laser with the category to which it belongs.

Laser Type
Laser Etcher
Skin Resurfacing Lasers
Laboratory Application Lasers
Precision-guided Munitions

	Laser Category
__________________	Industrial
__________________	Research
__________________	Military-Specific
__________________	Medical

Sources and Uses of Lasers in the Air Force (Page 5a of 8)

There is a variety of sources and uses of lasers throughout the Air Force. The primary categories of laser sources are **industrial**, **medical**, **research**, and **military-specific** lasers.

Industrial

Industrial laser sources found in the Air Force include:

- Laser etchers.
- Laser cutting devices.
- Micro drilling lasers.
- Carpentry alignment lasers.

Medical

Medical laser sources found in the Air Force include:

- LASIK eye surgery lasers.
- Dental procedure lasers.
- Skin resurfacing lasers.
- Endo-otoprobe procedure lasers used for ear surgeries.

Research

Research laser sources found in the Air Force include:

- Laboratory application lasers.
- Scientific and materials research lasers.

Military-Specific

Military-specific laser sources found in the Air Force include:

- Tactical high energy lasers.
- Targeting and navigation lasers.
- Laser markers (used with night vision goggles).
- Laser range finders.
- Laser warning systems.

Laser System Classifications (Page 6 of 8)

BE's primary role related to lasers is to evaluate the safe operation of laser systems and recommend appropriate controls when needed. Laser systems are classified based on wavelength and their capability to cause health effects to personnel. During isolated situations where laser systems are encountered that are not classified, you should contact the USAFSAM / ESOH Service Center for guidance.

Classification of new lasers in the Air Force is based on the most current standard from the American National Standard for Safe Use of Optical Radiation, ANSI Z136.1. However, existing lasers do not need to be reclassified to meet the most current standards. Therefore, because you will encounter lasers classified under the old system, it's important for you to be familiar with both the old system and the revised system, so you will be prepared to evaluate potential hazards associated with the lasers and recommend controls as needed.

Laser Classifications

Old Classification System	Revised Classification System
Class 1 Lasers	**Class 1 Lasers**
	Class 1M Lasers
Class 2 Lasers	**Class 2 Lasers**
	Class 2M Lasers
Class 3a Lasers	**Class 3R Lasers**
Class 3b Lasers	**Class 3B Lasers**
Class 4 Lasers	**Class 4 Lasers**

It's important to note that some commercially available lasers may be classified using the Food and Drug Administration's (FDA) standard. Refer to 21 CFR 1040.10 for more information if you encounter this classification system.

Old Classification System

Class 1 Lasers

Class 1 laser systems are low-powered systems considered incapable of causing injury during normal use. PPE is not required for this type of laser because all safety requirements are built into the laser, such as fully enclosing the beam.

Examples of Class 1 lasers include:

- Laser printers.
- CD players.
- CD-ROM devices.

Class 2 Lasers

Class 2 laser systems are low-powered, visible lasers with a wavelength between 400 and 700 nm. In order to be classified as a Class 2 laser, the power cannot be above 1 mW. Class 2 lasers cannot be an invisible laser.

PPE is not required for Class 2 lasers because the body's natural responses to bright light, known as the aversion response, offers adequate protection. The fastest aversion response is the eye blinking which can occur within 0.25 seconds.

Examples of Class 2 lasers include:

- Laser pointers.
- Aiming devices.
- Carpentry tools.

Class 3a Lasers

Class 3a lasers are moderate-powered, continuous-wave lasers where the power is 1-5 mW. This type of laser may be hazardous under direct viewing or in situations where the laser beam is reflected from shiny, mirror-like surfaces, known as specular reflection. Diffuse reflection, where the laser beam is bounced off a dull or uneven surface that breaks the beam apart, is usually not a hazard. Hazards from Class 3a lasers are increased with the use of optics such as glasses.

Examples of Class 3a lasers include:

- Range-finding equipment.
- Land surveying equipment.

Class 3b Lasers

Class 3b lasers are considered moderate-powered lasers and can be either continuous-wave or pulsed-wave lasers. Class 3b continuous-wave lasers are associated with power between 5 and 500 mW. Class 3b pulsed-wave lasers are associated with power between 0 and 10 Joules/cm^2.

The aversion response does not apply to this class of laser because injury can be caused in less than 0.25 seconds in any direct viewing, diffuse reflection, or specular reflection situation. Because of the hazards associated with Class 3b lasers, only trained personnel should operate them.

Examples of Class 3b lasers include:

- Lasers for entertainment light shows.
- Radiation spectrometry lasers.

Class 4 Lasers

Class 4 lasers are high-powered lasers with at least 500 mW of power. This type of laser is hazardous under any condition. Hazards associated with this type of laser are immediate eye damage, skin damage, and fire hazards. Class 4 lasers can be either continuous-wave or pulsed-wave systems.

Examples of Class 4 lasers include:

- Metal-cutting lasers.
- Micromachining lasers.
- Research drilling lasers.
- Lasers used for surgery.

Revised Classification System

Class 1 Lasers

Class 1 lasers are considered to be incapable of producing damaging radiation levels during operation, which allows them to be exempt from any control measures or other forms of surveillance.

Examples of Class 1 lasers include:

- Laser printers.
- CD players.
- Laser etchers.

Class 1M Lasers

Class 1M lasers are not capable of producing hazardous effects during normal operation unless the beam of the laser is viewed with an optical instrument such as an eye-loupe or a telescope. This type of laser is exempt from any controls or forms of surveillance measures other than to prevent potentially hazardous optical viewing.

An example of a Class 1M laser is fiber optic communications systems.

Class 2 Lasers

Class 2 laser systems emit energy in the visible portion of the electromagnetic spectrum between 400 and 700 nm. The natural body responses, such as the aversion response, normally offer adequate protection from this type of laser.

Examples of Class 2 lasers include:

- Classroom laser pointers.
- Alignment lasers.

Class 2M Lasers

Class 2M laser systems emit energy in the visible portion of the electromagnetic spectrum. The aversion response normally provides sufficient protection. However, Class 2M lasers are potentially hazardous if viewed with certain optical aids.

Examples of Class 2M lasers include:

- Levelers.
- Survey equipment.

Class 3R Lasers

Class 3R laser systems are potentially hazardous under some direct and specular reflection viewing conditions if the eye is appropriately focused and stable; however, the probability of actual injury is small.

Examples of Class 3R lasers include:

- Laser survey equipment.
- NeNe alignment lasers.

Class 3B Lasers

Class 3B laser systems may be hazardous under direct and specular reflection viewing conditions, but they are normally not a diffuse reflection or fire hazard.

Examples of Class 3B lasers include military illuminators and pointers.

Class 4 Lasers

Class 4 lasers are hazardous to the eyes and skin from direct beam exposures. In addition, this type of lasers poses diffuse reflection and fire hazards. Under certain conditions, Class 4 lasers can produce laser-generated air contaminants and hazardous plasma radiation.

Examples of Class 4 lasers include:

- Tactical high energy laser.
- Airborne lasers.
- Precision guided munitions.
- Laser weaponry.
- Targeting and navigation.

Appraisal (Page 7 of 8)

Following are several questions to check your knowledge about lasers. Select the correct answer for each question.

Using the old classification system, which one of the following types of lasers is considered incapable of causing injury during normal use?

A Class 1

B Class 1M

C Class 2M

D Class 4

Using the old classification system, how would intermediate-powered, continuous-wave lasers, where the power can be between 1-5 mW, be classified?

A Class 1

B Class 2

C Class 3a

D Class 4

Using the revised classification system, which one of the following types of lasers is potentially hazardous under some direct and specular reflection viewing conditions, if the eye is appropriately focused and stable?

A Class 2

B Class 2M

C Class 3B

D Class 3R

Using the revised classification system, which one of the following types of lasers is not capable of producing hazardous effects during normal operation unless the beam of the laser is viewed with an optical instrument such as an eye-loupe or a telescope?

A Class 1

B Class 1M

C Class 2M

D Class 3R

Lesson Summary (Page 8 of 8)

You've learned that lasers are defined as light amplified by the stimulated emission of radiation. Laser light is a form of concentrated energy that, with sufficient power and equipment design, can cut through any material. It travels in a small, tight beam with minimal spreading.

Sources and uses of lasers in the Air Force can include industrial, medical, research, or military-specific purposes. Laser systems are classified based on wavelength and their ability to cause health effects to personnel.

In this lesson you:

- Described the operating principles of lasers.
- Recalled components of lasers.
- Listed sources and uses of lasers in the Air Force.
- Recognized parameters required to classify a laser system.

Audio Script

Narrator: After reviewing the notes from the previous year's workshop and preparing your materials, you conduct the training with the BE personnel. During the workshop, you discuss the operating principles of lasers, the components of lasers, and the parameters used for classifying laser hazards in the Air Force under the old and new classification systems.

Lesson 2: Analyzing Laser Hazards

Lesson Description

In this lesson, you will conduct an HRA that will include analyzing a new laser a the lab on base. Upon completion of this lesson, you will be able to describe the biological effects caused by laser exposures, explain how hazards are identified and analyzed, and describe the Maximum Permissible Exposure (MPE), Nominal Ocular Hazard Distance (NOHD), and Nominal Hazard Zone (NHZ).

Lesson Overview (Page 1 of 9)

When identifying and analyzing laser hazards, you should follow the OEHSA process to provide the most appropriate recommendations to protect personnel.

While you're conducting the HRA at the lab, you will:

- Associate potential biological effects to the energy of a laser.
- Determine why and when laser hazard identification and analysis should occur.
- Recognize the steps for identifying and analyzing laser hazards and assessing the health risk.
- Describe the Maximum Permissible Exposure (MPE), Nominal Ocular Hazard Distance (NOHD), and Nominal Hazard Zone (NHZ).

Audio Script

NCOIC: The lab on base has purchased a new laser they'll be using for biomedical imaging and analysis purposes. I got an email about it this morning from the lab supervisor, but the message didn't contain much information about the specifics of how the laser will be set up.

I need you to conduct an HRA at the lab to ensure personnel are working in safe conditions around the new laser. I've scheduled an appointment for you this afternoon at 14:00 with the lab supervisor.

In the meantime, I've forwarded you the email with the information I have about the laser.

Jillsong Base Scenario (Page 2 of 9)

FW: Acceptance of new laser system.

From: AF Labs

To: Bioenvironmental Engineering

Subject: Acceptance of new laser system.

Importance: High

This message is to notify you about a new laser the lab has purchased for biomedical imaging and analysis purposes. I've included some basic information about the laser below.

Laser Name: Excel 532 nm high power, low divergence laser
Laser Classification: Class 4 (Continuous Wave System)
Power: 1, 1.5, 2 Watts
Wavelength: 532 nm
Beam Size: 1.8 mm
Divergence: 0.5 mrad

If you need additional information or would like to meet, please let me know.

Regards,

Jane Dawns

Supervisor, AF Labs

Audio Script

Narrator: While reading the email that your NCOIC forwarded, you discover the new laser is a Class 4, high powered laser, commonly used in laboratory environments.

Scenario Challenge Point (Page 3 of 9)

Given the information provided in the email, you review the factors contributing to potential biological effects of laser exposures so you are better positioned to begin the HRA at the lab this afternoon.

Which two of the following are potential biological effects associated with laser exposures from systems like the one purchased by the lab?

A Thermal Damage

B Nervous System Damage

C Photochemical Damage

D Respiratory System Damage

Biological Effects of Laser Exposure (Page 3a of 9)

As a laser exposure exceeds permissible levels, the **potential for damaging biological effects** increases. As a general rule, tissues will either transmit or absorb energy from a laser. If the tissue transmits energy, the tissue structures are not damaged. If the tissue absorbs energy, the laser wavelength can damage the tissue structures.

When analyzing laser hazards, you should primarily be concerned about **the eyes**. A secondary organ of concern is **the skin**.

Biological tissue damage associated with laser exposures includes:

- **Thermal Damage.**
- **Photochemical Damage.**

Potential for Biological Effects

Factors contributing to the biological effects of laser exposures include:

- Type of organ exposed.
- Laser wavelength.
- Total energy absorbed.
- Number of pulses.
- Size of beam on cornea or in lens.
- Size of image on retina.
- Exposure duration.
- Cumulative exposures.

Biological Effects to Eyes

Biological effects from laser exposures to the eye include:

- Retinal injuries such as thermal coagulation, formation of blind spots, significant loss of vision, optical obstruction and retinal burns leading to blindness.
- Corneal injuries such as cataracts and corneal discoloration.
- Lens injuries such as cataract formation, visual focusing impairment, and blurred vision.

Biological Effects to Skin

Biological effects from laser exposures to the skin include:

- Photochemical and thermal burns.
- Increased risk of skin cancer.
- Premature aging.
- Increased pigmentation.

Thermal Damage

Thermal damage is brought about by the temperature elevation of a substance due to laser exposure. This occurs when a steady stream of photons is absorbed by the tissue until the natural cooling ability of the tissue is overwhelmed and its temperature rises to damaging levels.

For example, when a laser hits the cornea and lens of an eye, it causes a cataract-like heating effect that damages the eye. The common health effects associated with thermal damage include:

- Permanent retinal damage.
- Short-term tissue damage.
- Energy absorption and heat build-up.
- Long-term heat build-up from a sustained exposure.

Photochemical Damage

Photochemical damage is damage to individual cells brought about by the absorption of photons by molecules that directly alter the molecule. When an exposure of this type occurs, intense heat-build up changes the chemistry of the cells and causes toxic chemical reactions in the tissue and long-term effects.

Scenario Challenge Point (Page 4 of 9)

Before you begin your HRA, you reflect on the process for identifying and analyzing laser hazards. Select the correct answer or answers for the questions below.

Which of the following statements describe when laser hazards should be identified and analyzed?

A Any time a laser is used for operations on an installation.

B When annual compliance testing is required by regulations.

C When a shop's mission changes, causing lasers to be removed.

D Any time a laser has not been assessed for personnel exposure.

Which two of the following are primary reasons why laser hazards should be identified and analyzed?

A To determine the criticality of the mission using laser systems.

B To gather appropriate information needed to classify a laser system.

C To determine if a laser hazard could impact mission effectiveness.

D To determine if a potential or existing laser exposure poses a health risk.

Identify and Analyze Laser Hazards (Page 4a of 9)

When evaluating any potential health risk, including those posed by laser hazards, you should use the Health Risk Assessment (HRA) and Occupational and Environmental Health Site Assessment (OEHSA) processes. When a laser used in base operations has not been assessed for personnel exposure, the laser hazards should be identified and analyzed.

Once the risk is identified, laser hazards are analyzed to determine:

- Why is the laser hazard a potential or actual problem?
- Are there other potential threats surrounding the laser hazard?
- Does the laser hazard impact operations or mission effectiveness?
- Is there a potential for exposure variability?

It's important to identify and analyze laser exposure situations so appropriate controls can be recommended to prevent adverse health effects.

Scenario Challenge Point (Page 5 of 9)

As you begin gathering information for the HRA, you follow the OEHSA process to provide the data needed for the laser hazards. Match each task you perform when *identifying* laser hazards with the appropriate step in the OEHSA process by marking the appropriate block in the table.

Description	Predeployment / Baseline Activities	Site Identification / Sectoring	Site Reconnaissance
Perform a site visit to confirm the information that has been gathered.			
Obtain any available information about existing lasers in the AOC and their classifications.			
Define the area of responsibility (AOR), area of operations (AO), and missions associated with the hazard.			

Steps for Indentifying and Analyzing Laser Hazards (Page 5a of 9)

Effectively identifying laser hazards is important in determining the potential health risks associated with lasers. Many shops in the Air Force use lasers, but many of the shop workers don't recognize them as being dangerous. Because of this, it is difficult to identify all laser hazards through interviews with personnel. This means you may have to perform additional surveillance using a variety of methods to determine all laser hazards present in a particular area of concern (AOC).

When identifying laser hazards, you should follow the first three steps in the OEHSA process to gather the appropriate information about the potential health threat.

- **Predeployment / Baseline Activities**
- **Site Identification / Sectoring**
- **Site Reconnaissance**
- Conceptual Site Model (CSM)
- Initial / Specialized Surveillance
- Reassessment

Predeployment / Baseline Activities

During the predeployment / baseline activities step of OEHSA, you should first obtain any available information about existing lasers in the AOC and their classifications.

Site Identification / Sectoring

During the site identification and sectoring phase of OEHSA, you should use the information gathered to determine which personnel may be affected by the laser hazards. This is done by defining the area of responsibility (AOR), area of operations (AO), and missions associated with the laser hazards.

Site Reconnaissance

Once the first two phases of the OEHSA process have been conducted, you should perform a site visit to confirm the information you have gathered to this point and visually inspect both beam and non-beam hazards. You should also obtain **laser parameters** at this time.

While at the site, you may conduct interviews with personnel who operate the lasers or work around the lasers. You should document any conditions that may indicate potentially hazardous workplaces or operations related to the laser hazards, including specular and diffusion reflections and fire hazards. You should also make note of the use and standard operating procedures for PPE in the area around the hazards.

Laser Parameters

Laser parameters you should obtain during Site Reconnaissance include:

- Wavelength.
- Exposure duration.
- Optical power.
- Beam divergence.
- Aperture beam diameter.
- Any applicable pulse specifications.

Jillsong Base Scenario (Page 6 of 9)

Audio Script

BE Tech: Good afternoon, Ms. Dawns. Thank you for meeting with me today.

Supervisor: I'm glad to help.

BE Tech: I hear the lab has purchased a new laser.

Supervisor: Yes, we just received it last week. It'll be used in our biomedical research department.

BE Tech: I'd like to conduct an assessment in that department to make sure the area is safe for personnel operating the laser.

Supervisor: Okay, please feel free to look around and conduct your assessment. If you need additional information about the laser, please let me know. I've also included some documentation materials next to the laser system if you need those.

BE Tech: Thank you for your help.

Scenario Challenge Point (Page 7 of 9)

After gathering the information about the laser, which one of the following tasks should you perform next?

A	Recommend appropriate controls which address both specular and diffuse laser reflection hazards.
B	Determine the Maximum Permissible Exposure, Nominal Ocular Hazard Distance, and Nominal Hazard Zone.
C	Perform surveillance with measuring equipment to determine which personnel may be affected by the laser hazards.
D	Interview personnel who work around the laser hazard to confirm the information you have gathered for beam and non-beam hazards.

Steps for Indentifying and Analyzing Laser Hazards (Page 7a of 9)

Once you have identified the health threats associated with lasers, it's critical to analyze them within the context of the mission through the conceptual site model and initial / specialized surveillance steps in the OEHSA process.

- Predeployment / Baseline Activities
- Site Identification / Sectoring
- Site Reconnaissance
- **Conceptual Site Model (CSM)**
- **Initial / Specialized Surveillance**
- Reassessment

Conceptual Site Model (CSM)

When you are performing an OEHSA that includes lasers, you should document the laser hazards in the assessment's Conceptual Site Model (CSM). The information referenced in the CSM related to laser hazards should contain details about the areas and personnel affected by the health risk.

Initial / Specialized Surveillance

During the initial / specialized surveillance phase of the OEHSA process, you should work to quantify the health risks associated with laser hazards.

The Laser Hazard Analysis Software (LHAZ) computer program is the primary resource you should use to calculate characteristics about the laser hazards in question. The information calculated from this system helps to determine the laser system's capability of injuring personnel or interfering with mission performance, the environment in which the laser may be used, and the personnel who may use or be exposed to the laser's radiation. If you are missing parameters for the LHAZ software, you should contact USAFSAM for guidance.

Calculations performed with LHAZ include the **Maximum Permissible Exposure (MPE)**, **Nominal Ocular Hazard Distance (NOHD)**, and **Nominal Hazard Zone (NHZ)**.

Determining the MPE, NOHD, and NHZ enables you to identify the amount and type of energy a person can be exposed to before the exposure becomes hazardous at a certain distance. For example, if you know that a laser presents a hazard to the eyes at 5 feet from the laser's aperture, you can recommend appropriate controls to address the specific hazard.

Maximum Permissible Exposure (MPE)

The Maximum Permissible Exposure (MPE) is the level of laser radiation to which a person may be exposed without hazardous effects or adverse biological changes in the eyes or skin. MPEs are typically calculated in relation to the eyes and skin because these are two critical organs associated with laser exposures.

Nominal Ocular Hazard Distance (NOHD)

The Nominal Ocular Hazard Distance (NOHD) is the distance along the laser beam beyond which the exposure is not expected to exceed the appropriate MPE. The NOHD is the basis for determining the NHZ.

Nominal Hazard Zone (NHZ)

The Nominal Hazard Zone (NHZ) is the area within a laser workplace in which the exposure from direct beam, specular reflection, and diffuse reflection could exceed the MPE. The purpose of the NHZ is to define the region where control measures are required.

Appraisal (Page 8 of 9)

Match each calculation with the appropriate description associated with laser hazards.

Calculations
NHZ
MPE
NOHD

	Descriptions
___________________	The level of laser radiation to which a person may be exposed without hazardous effects or adverse biological changes in the eyes and skin.
___________________	The distance along the laser beam beyond which the exposure is not expected to exceed the maximum limit.
___________________	The area within a laser workplace in which the exposure from a direct beam, specular reflection, and diffuse reflection could exceed the maximum limit.

Lesson Summary (Page 9 of 9)

When analyzing any type of radiation hazard, it's important to determine the amount and type of energy a person can be exposed to before that exposure becomes hazardous. When analyzing laser hazards, you should use the Maximum Permissible Exposure (MPE), Nominal Ocular Hazard Distance (NOHD), and Nominal Hazard Zone (NHZ) to determine safe limits for personnel working around lasers. This information is used to protect personnel from potential biological health effects associated with laser exposures.

In situations where lasers need to be identified and analyzed, you should use the HRA and OEHSA processes to gather and determine results from data so you can recommend appropriate controls.

In this lesson you:

- Associated potential biological effects to the energy of a laser.
- Determined why and when laser hazard identification and analysis should occur.
- Recognized the steps for identifying and analyzing laser hazards and assessing the health risk.
- Described the Maximum Permissible Exposure (MPE), Nominal Ocular Hazard Distance (NOHD), and Nominal Hazard Zone (NHZ).

Audio Script

Narrator: After conducting the HRA, you determine the laser should be operated only by personnel with appropriate training. You also recommend additional controls in the shop to reduce risks for specular and diffuse reflection hazards.

Lesson 3: Laser Control Options

Lesson Description

In this lesson, you will conduct an HRA at the MTF on base where you will identify and analyze a laser hazard and recommend appropriate controls. Upon completion of this lesson, you will be able to determine laser control options for a given situation.

Lesson Overview (Page 1 of 9)

Once a laser hazard is identified and analyzed, control measures must be recommended to protect personnel from hazardous exposures.

While conducting the routine assessment at the MTF, you will:

- Recall control requirements for lasers.
- Determine if PPE for lasers is used and maintained in accordance with established guidelines.
- Select appropriate PPE for lasers, given hazards and equipment limitations.
- Determine appropriate controls.

Audio Script

Narrator: During your BE shop's routine morning meeting, your OIC reviews several tasks that need to be accomplished. One of the tasks mentioned is conducting a routine HRA at the MTF on base. You volunteer to take the assignment since you have worked with the personnel at the MTF before.

After the meeting concludes, you make an appointment with the MTF supervisor and travel to the facility to begin the assessment.

Jillsong Base Scenario (Page 2 of 9)

When you arrive at the MTF, you meet with the facility supervisor to identify any major changes that have occurred since the last HRA was conducted.

Audio Script

BE Tech: Good morning.

MTF Facility Supervisor: Hi. How can I help you today?

BE Tech: I'm conducting a routine assessment to make sure personnel here at the MTF are not exposed to any undue health threats.

MTF Facility Supervisor: Is there anything specific you're looking for?

BE Tech: I'm actually going to be looking for a variety of things around the facility; however, I'd like to begin by identifying anything that has changed since the last time an assessment was conducted.

MTF Facility Supervisor: Well…I think most everything has stayed about the same around here.

BE Tech: Are you aware of any changes to the procedures or processes around the facility or have any personnel been relocated?

MTF Facility Supervisor: The only change I can think of is we're moving an optometrist's office from the 4th floor to the 5th floor so there's more room for patients. They're just about done with the remodeling.

BE Tech: What types of procedures are performed at that office?

MTF Facility Supervisor: In addition to regular vision testing, they use a surgical laser for LASIK outpatient procedures.

BE Tech: Did the area where the optometrist's office is moving to contain any lasers before?

MTF Facility Supervisor: No. That area used to be a waiting room for another department.

BE Tech: If you don't mind, I'd like to begin there.

MTF Facility Supervisor: That's fine. I'll call up to the office and have the office manager meet you on the 5th floor. Let me know if you need any assistance while you're here.

BE Tech: I sure will. Thank you, Sir.

Narrator: After concluding your conversation with the supervisor, you make your way to the optometrist's office.

Jillsong Base Scenario (Page 3 of 9)

Audio Script

BE Tech: Good morning. I'm with Bioenvironmental Engineering and I'm conducting a health assessment here at the MTF.

Office Manager: Oh, yeah, the supervisor let me know you'd be coming by. How can I help you?

BE Tech: I was told this office is new to this location and that LASIK procedures will be performed here.

Office Manager: Yes, we're about finished installing the medical equipment in each of the exam rooms. The surgical laser was installed earlier this week. We should start seeing patients in the new office next week.

BE Tech: Can you direct me to the room where the laser used for the LASIK procedures is located?

Office Manager: I sure can. Go to the end of the hall and make the first right. It's the room at the end of the hallway. The technician who normally oversees the laser is also here today. Would you like me to have her meet you there?

BE Tech: That would be great. Thanks.

Narrator: You make your way to the room where the LASIK procedures will be performed to begin gathering information about the laser.

Scenario Challenge Point (Page 4 of 9)

While you are waiting for the technician, you begin to document the parameters of the laser and identify any controls that are currently in place in the operating room. Which one of the following engineering controls for laser hazards should be used, whenever feasible, because it significantly reduces the need for other controls?

A Warning Systems

B System Interlocks

C Education and Training

D Restrict Access to Laser

E Enclose the Beam Path

Control Requirements for Lasers Challenge Point (Page 4a of 9)

Control requirements for laser hazards are used to reduce the possibility of laser exposures causing direct or indirect health effects. Control measures are primarily designed to reduce the possibility of exposure to the eyes and skin, the critical organs for laser hazards. Appropriately implemented controls should prevent ocular exposure from both the primary beam and any specular reflections. As always, control recommendations should follow the hierarchy of controls. Laser hazards can be controlled using engineering controls, administrative controls, and PPE.

Tab: Engineering Controls

Engineering controls commonly used to control laser hazards include:

- **Beam path enclosures.**
- **Protective housings.**
- **System interlocks.**
- **Warning systems.**
- **Remote operation.**

Beam Path Enclosures

Enclosing the beam path is the most effective engineering control and should be implemented whenever feasible. Use of enclosures will significantly reduce the need for other controls.

Protective Housings

Protective housings can be obtained from the manufacturer to prevent access to laser radiation which exceeds the intended classification limits.

System Interlocks

System interlocks are designed to prevent access by electrically or mechanically interrupting the aperture or to shut off the power to the laser when the protective beam enclosure is opened or removed.

Warning Systems

Warning systems should be implemented inside the laser control area to protect personnel who work around the laser. Examples of warning systems include alarms, warning lights, or verbal “countdown” commands during laser activation or startup.

Remote Operation

Remote operation protects personnel from hazardous exposures by allowing them to operate the laser system from a distance rather than near the laser source.

Tab: Administrative Controls

Administrative controls primarily focus on training personnel who will be working with or near lasers about proper operation and maintenance, according to Air Force standards. Personnel should be trained to employ standard operating procedures which are established for the proper use, alignment, and maintenance of laser systems, including:

- **Containing the laser beam.**
- **Avoiding reflective surfaces.**
- **Controlling access.**
- **Posting signs.**

Containing the Laser Beam

Because looking into the beam of a laser can cause permanent damaging health effects such as blindness, the laser beam should be maintained at a level other than the normal eye level of a person who is sitting or standing.

Avoiding Reflective Surfaces

Laser beams may reflect off shiny surfaces causing the potential for damage from the reflection. Therefore, personnel should avoid placing objects in the area around the laser that would cause the beam to reflect.

Controlling Access

Because lasers can be hazardous to personnel, access to the laser should be allowed only for individuals who are trained and aware of the proper safety practices.

Posting Signs

Signs should be posted in areas where laser hazards are present based on the laser classification.

Tab: Personal Protective Equipment

PPE for laser hazards is designed to control exposures to the eyes and skin.

PPE for Exposures to the Eyes

Laser Eye Protection (LEP) must be worn when working around hazardous lasers unless engineering or administrative controls eliminate the exposure.

LEP must be matched to the specific wavelength of the laser and have an optical density rating high enough to protect personnel against the power of that particular laser.

Examples of LEP include:

- Goggles.
- Face shields.
- Prescribed glasses with special protective coatings.

PPE for Exposures to the Skin

Laser hazards affecting the skin should be controlled through engineering controls that terminate or enclose the laser radiation. However, if engineering controls are not sufficient, you should use sunscreens for UV exposures, gloves to protect the skin from burns, and protective clothing such as a lab jacket. For higher powered lasers, you should also consider PPE made from flame-retardant materials.

Jillsong Base Scenario (Page 5 of 9)

Audio Script

Laser Technician: Hi, how can I help you today?

BE Tech: I'm conducting an assessment to make sure the appropriate precautions are in place for personnel who work in the MTF. I was told this office is in a new location and includes a laser used for LASIK procedures. Is that the only laser located in the office?

Laser Technician: Yes, we've had the laser for several years and conduct about 200 LASIK procedures a year.

BE Tech: Can you tell me about the parameters of the laser?

Laser Technician: Well, not off the top of my head, but I have the user's manual here because I was checking on something else. Let me see. . . . Oh, here it is. This is an Excimer Class 3B laser with a power of 300 mW.

BE Tech: Thanks. I also need to know the wavelength and optical density assigned to the device.

Laser Technician: It says here the wavelength of the laser is 300 nm and the optical density requirement is 6.

BE Tech: Has the laser ever been modified or the strength changed?

Laser Technician: No, not that I'm aware of.

BE Tech: What type of PPE is used when working with the laser?

Laser Technician: We wear standard surgical scrubs and use laser safety glasses.

BE Tech: Do you know what type of glasses you use?

Laser Technician: We actually had to order new glasses for the surgical team because the glasses we used in the old location were sent to storage during the move and were lost. I can look that information up for you.

BE Tech: That would be great. Do you have a copy of the latest laser inspection report I could look at as well?

Laser Technician: Absolutely. I'll also bring you some more detailed information about the laser system just in case you need it.

BE Tech: Thank you. I appreciate your help.

Scenario Challenge Point (Page 6 of 9)

When the technician returns with the information about the inspection report and the laser specifications, she also brings a pair of the new laser safety glasses that were ordered for the surgical team.

Based on the information you've learned about the laser system to this point (provided below), will the laser safety glasses be sufficient to protect personnel working around the laser?

A Yes

B No

Scenario Challenge Point (Page 7 of 9)

You've determined that the new eye protection purchased for use with the laser in the LASIK surgical room is not sufficient to protect personnel. Now you need to select appropriate eye protection. Keeping in mind that the Class 3B laser system they are using has a wavelength of 300 nm and an optical density of 6, based on the specifications below, which two of the following types of laser eye protection would be appropriate?

A Wavelength: 510-680 nm
OD: 6+

B Wavelength: 850-900 nm
OD: 3+

C Wavelength: 190-380 nm
OD: 6+

D Wavelength: 1,000-1,600 nm
OD: 7+

E Wavelength: 190-450 nm
OD: 6+

Control Requirements for Lasers Challenge Point (Page 7a of 9)

In order to recommend the appropriate LEP, you should consider several factors related to LEP selection. All protective eye wear must be clearly labeled with the optical density and wavelength to be able to determine the proper use for the device. The factors to consider for LEP selection are:

- **Wavelength**
- **Optical Density (OD) Requirements**
- **Angular Dependence**
- **Eyewear Damage**
- **Comfort and Fit**
- **Capability of Specular Reflection**

Wavelength

When selecting LEP, you should make sure the wavelength for the LEP sufficiently matches the laser's wavelength. You should also consider the potential for multi-wavelength operations such as tunable lasers to ensure the LEP is appropriate for the wavelengths that can be produced.

Optical Density (OD) Requirements

The Optical Density (OD) is a unit-less number assigned during laser classification that describes the amount of energy that needs to be blocked in order to be protected from that laser.

The OD rating must be provided on the LEP and describes the amount of light energy the LEP lens blocks. It's important for the OD to be high enough to protect personnel from the laser while still allowing enough light through so work can be performed.

The OD for LEP is typically found on the ear piece or is etched on the front of the glasses.

Angular Dependence

The angular dependence of the LEP you select is important to ensure that personnel wearing the device are protected from all angles of viewing.

Eyewear Damage

When evaluating the proper use and maintenance of LEP, you should make sure the device does not have any scratches or damage to the lens.

If an absorptive LEP is scratched, it could still be functional. However, deep scratches reduce the amount of protection that may be provided by the LEP.

Reflective LEP such as those made from coated glass are not tolerant to scratches.

When the reflective coating from this type of LEP is removed or scratched, the glasses should not be used.

Comfort and Fit

The comfort and fit of the LEP are very important because if it is not comfortable, personnel may not wear it or may not use it properly. If LEP is not properly fitted, it can create gaps around the glasses that will allow laser light through to the eye.

For example if a laser operator wears prescription glasses, then LEP must be selected that properly fits over the prescription lenses.

Also, if LEP must be removed to be cleaned or readjusted for comfort while operating a laser the LEP is of no use while it is not being worn,

Capability of Specular Reflection

When selecting LEP, you should consider the potential for specular reflection from reflective lenses. This can endanger other workers who may come in contact with the reflection from the laser off of the lens.

Scenario Challenge Point (Page 8 of 9)

In addition to determining that different LEP needs to be implemented, you begin to develop other appropriate recommendations for controls. Using the information you've written on your notepad and the ANSI standards related to laser hazard controls (supplied in the Appendix of this document), determine the appropriate controls needed to protect personnel from the laser hazard in the LASIK surgical room.

Which one of the following types of signs should be used outside the surgical room?

A CAUTION

B DANGER

C NOTICE

Which one of the following is true regarding the use of interlocks with this laser system?

A Interlocks are not required.

B Interlocks are recommended.

C Interlocks are required.

Which of the following is true regarding the use of LEP with this laser system?

A LEP is not required.

B LEP is recommended.

C LEP is required.

Which one of the following is true regarding use of protective barriers and curtains with this laser system?

A Protective barriers and curtains are not required.

B Protective barriers and curtains are optional.

C Protective barriers and curtains are required.

Which one of the following is true regarding the operation of this laser system?

A Authorized personnel are not required to operate the laser.

B Authorized personnel are recommended to operate the laser.

C Authorized personnel are required to operate the laser.

Which one of the following is true regarding the education and training of personnel who work with and around the laser system?

A Education and training is not required.

B Education and training is recommended.

C Education and training is mandatory.

Class Specific Laser Controls (Page 8a of 9)

In addition to selecting general control requirements for laser hazards, you should identify controls related to the classifications of lasers as provided in the most current ANSI Z136.1 Standards.

Laser Classifications

Old Classification System	Revised Classification System
Class 1 Lasers	**Class 1 Lasers**
	Class 1M Lasers
Class 2 Lasers	**Class 2 Lasers**
	Class 2M Lasers
Class 3a Lasers	**Class 3R Lasers**
Class 3b Lasers	**Class 3B Lasers**
Class 4 Lasers	**Class 4 Lasers**

Old Classification System

Class 1 Lasers

Specific controls associated with Class 1 lasers include:

- Optional posting of “Low-Powered Laser” warning signs in the area.
- Required labeling of the laser with its characteristics.

Class 2 Lasers

Specific controls associated with Class 2 lasers include:

- Required posting of “Caution” warning signs in the area.
- Optional control of spectator access.
- Optional beam blocking.
- Optional control of viewing ports and optics.

Class 3a Lasers

Specific controls associated with Class 3a lasers include:

- Required posting of “Caution” or “Danger” warning signs in the area.
- Establishment of nominal hazard zone (NHZ) for outdoor use.
- Possible implementation of LEP.

Class 3b Lasers

Specific controls associated with Class 3b lasers include:

- Baseline eye examination.
- Direct supervision of spectators by the operator.
- Recommendation of LEP use.
- Required posting of “Danger” warning signs in the area.
- Requirement for authorized operators.
- Requirement for key-operated master switch.
- Requirement for beam stops.
- Requirement for use of interlocks.

Class 4 Lasers

Specific controls associated with Class 4 lasers include:

- Implementation of all required controls for the lower laser classifications.
- Required posting of “Danger” warning signs in the area.
- Requirement for the most stringent controls such as physical barriers to block laser radiation and protective clothing.
- Requirement for standard operating procedures.

Revised Classification System

Class 1 Lasers

There are no controls specifically associated with Class 1 lasers.

Class 1M Lasers

Specific controls associated with Class 1M lasers include:

- Standard operating procedures.
- Training.

Class 2 Lasers

Specific controls associated with Class 2 lasers include:

- Standard operating procedures.
- Training.
- Optional posting of “Caution” signs.

Class 2M Lasers

Specific controls associated with Class 2M lasers include:

- Standard operating procedures.
- Training.
- Optional posting of “Caution” signs.

Class 3R Lasers

Specific controls associated with Class 3R lasers include:

- Standard operating procedures.
- Training.
- Required posting of “Danger” signs.

Class 3B Lasers

Specific controls associated with Class 3B lasers include:

- LEP.
- Protective housings.
- Interlocks.
- Required posting of “Danger” signs.

Class 4 Lasers

Specific controls associated with Class 4 lasers include:

- LEP.
- Protective housings.
- Interlocks.
- Required posting of “Danger” signs.

Lesson Summary (Page 9 of 9)

Control requirements for laser hazards are used to reduce the possibility of laser exposures which can cause direct or indirect health effects. The primary organs of concern for laser hazards are the eyes and skin.

You should use the hierarchy of controls to implement engineering controls first, administrative controls second, and then PPE, if additional protection is required. As a general requirement, you should work to enclose the beam path of the laser first because this will significantly reduce the need for other controls. You should ensure your control recommendations are appropriate for the specific class of laser being used.

In this lesson you:

- Recalled control requirements for lasers.
- Determined if PPE for lasers is used and maintained in accordance with established guidelines.
- Selected appropriate PPE for lasers, given hazards and equipment limitations.
- Determined appropriate controls for lasers.

Audio Script

Narrator: After completing the HRA, you meet with the MTF facility supervisor to present your recommendations for controls pertaining to the LASIK surgical room. The recommended controls were implemented into the new surgical area before the office began seeing patients.

Resources

- AFOSH Std 48-139, Laser Radiation Protection Program
- ANSI Z136.1-2007, American National Standard for Safe Use of Lasers
- Helpful Tables in ANSI Z136.1
    - Table H2a, *Comparison of National and International Standards for Classification*
    - Table 10, *Control Measures for the Seven Laser Classes*
    - Table 11a, *Summary of Area Warning Signs*

Answer Key: Appraisals / Scenario Challenge Points

Lesson 1: Fundamentals of Lasers

Page 2 of 8

Which one of the following statements is the correct definition of a laser?

B Light amplification by stimulated emission of radiation

Rationale: Lasers are defined as light amplification by stimulated emission of radiation.

Page 4 of 8

Match each component of a laser system with its function by marking the appropriate block in the table.

Description	Pumping System	Medium	Optical Cavity
This component is the source of the laser photon energy.		X	
This component focuses and amplifies photon energy in a laser beam.			X
This component excites the electrons so they give off photon energy.	X		

Rationale: The pumping system is used to create a situation where there are more excited electrons giving off photon energy than there are electrons in a normal state. The medium is the source of the laser photon energy. The optical cavity acts like a resonant feedback system that focuses and amplifies photon energy in a laser beam.

Page 5 of 8

To help the participants in your workshop identify where they may find laser sources at their base, as one of your visual aids, you decide to list several examples of lasers commonly found in the Air Force.

Match each type of laser with the category to which it belongs.

Laser Type	Laser Category
Laser Etcher	Industrial
Laboratory Application Lasers	Research
Precision-guided Munitions	Military-Specific
Skin Resurfacing Lasers	Medical

Rationale: Laser etchers are examples of industrial lasers. Skin resurfacing lasers are examples of medical lasers. Laboratory application lasers are considered research lasers. Precision-guided munitions are military-specific lasers.

Page 7 of 8

Following are several questions to check your knowledge about lasers. Select the correct answer for each question.

Using the old classification system, which one of the following types of lasers is considered incapable of causing injury during normal use?

A Class 1

Using the old classification system, how would intermediate-powered, continuous-wave lasers, where the power can be between 1-5 mW, be classified?

C Class 3a

Using the revised classification system, which one of the following types of lasers is potentially hazardous under some direct and specular reflection viewing conditions, if the eye is appropriately focused and stable?

D Class 3R

Using the revised classification system, which one of the following types of lasers is not capable of producing hazardous effects during normal operation unless the beam of the laser is viewed with an optical instrument such as an eye-loupe or a telescope?

B Class 1M

Lesson 2: Analyzing Laser Hazards

Page 3 of 9

Given the information provided in the email, you review the factors contributing to potential biological effects of laser exposures so you are better positioned to begin the HRA at the lab this afternoon.

What are two potential biological effects associated with laser exposures from systems like the one purchased by the lab?

A Thermal Damage

C Photochemical Damage

Rationale: Thermal damage is brought about by the temperature elevation of a substance due to laser exposure. Photochemical damage is damage to individual cells brought about by the absorption of photons by molecules that directly alter the molecule. Nervous system damage and respiratory system damage are not commonly associated with laser exposures.

Page 4 of 9

Before you begin your HRA, you reflect on the process for identifying and analyzing laser hazards. Select the correct answer or answers for the questions below.

Which statement describes when laser hazards should be identified and analyzed?

D Any time a laser has not been assessed for personnel exposure.

What are two primary reasons why laser hazards should be identified and analyzed?

C To determine if a laser hazard could impact mission effectiveness.

D To determine if a potential or existing laser exposure poses a health risk.

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As you begin gathering information for the HRA, you follow the OEHSA process to provide the data needed for the laser hazards. Match each task you perform when *identifying* laser hazards with the appropriate step in the OEHSA process by marking the appropriate block in the table.

Description	Predeployment / Baseline Activities	Site Identification / Sectoring	Site Reconnaissance
Perform a site visit to confirm the information that has been gathered.			X
Obtain any available information about existing lasers in the AOC and their classifications.	X		
Define the area of responsibility (AOR), area of operations (AO), and missions associated with the hazard.		X	

Rationale: When using the OEHSA process to provide data for the HRA, you should obtain any available information about existing lasers in the AOC and their classifications during the predeployment / baseline activities step. During the site identification / sectoring step, you should define the area of responsibility (AOR), area of operations (AO), and missions associated with the laser hazard. During the site reconnaissance step, you should perform a site visit to confirm the information that has been gathered.

Page 7 of 9

After gathering the information about the laser, which task should you perform next?

B **Determine the Maximum Permissible Exposure, Nominal Ocular Hazard Distance, and Nominal Hazard Zone.**

Rationale: After gathering information, you should determine the MPE, NOHD, and NHZ because there is no measurement equipment available for laser hazards. You should interview personnel while you are collecting information about the hazard. You should recommend appropriate controls after the hazard has been fully analyzed.

Page 8 of 9

Match each calculation with the appropriate description associated with laser hazards.

Calculations	Descriptions
NHZ	The level of laser radiation to which a person may be exposed without hazardous effects or adverse biological changes in the eyes and skin.
MPE	The distance along the laser beam beyond which the exposure is not expected to exceed the maximum limit.
NOHD	The area within a laser workplace in which the exposure from a direct beam, specular reflection, and diffuse reflection could exceed the maximum limit.

Rationale: The MPE is the level of laser radiation to which a person may be exposed without hazardous effects or adverse biological changes in the eyes or skin. The NOHD is the distance along the laser beam beyond which the exposure is not expected to exceed the appropriate MPE. The NHZ is the area within a laser workplace in which the exposure from direct beam, specular reflection, and diffuse reflection could exceed the MPE.

Lesson 3: Laser Control Options

Page 4 of 9

While you are waiting for the technician, you begin to document the parameters of the laser and identify any controls that are currently in place in the operating room. Which engineering control for laser hazards should be used, whenever feasible, because it significantly reduces the need for other controls?

E Enclose the Beam Path

Rationale: The correct answer is now displayed. Enclosing the beam path is the most effective engineering control and should be used whenever it's feasible to implement. Use of enclosures will significantly reduce the need for other controls. Warning systems and system interlocks are engineering controls; however, they do not reduce the need for other controls. Education and training and restricting access to the laser are both administrative controls.

Page 6 of 9

When the technician returns with the information about the inspection report and the laser specifications, she also brings a pair of the new laser safety glasses that were ordered for the surgical team. Based on the information you've learned about the laser system to this point (provided below), will the laser safety glasses be sufficient to protect personnel working around the laser?

B No

Rationale: The correct answer is now displayed. The new eye protection that was purchased is not sufficient for the laser in question because the wavelength range for the LEP does not match the wavelength of the laser and the OD requirement for the laser is greater than indicated OD on the LEP.

Page 7 of 9

You've determined that the new eye protection purchased for use with the laser in the LASIK surgical room is not sufficient to protect personnel. Now you need to select appropriate eye protection. Keeping in mind that the Class 3B laser system they are using has a wavelength of 300 nm and an optical density of 6, based on the specifications below, which two of the following types of laser eye protection would be appropriate?

C Wavelength: 190-380 nm
OD: 6+

E Wavelength: 190-450 nm
OD: 6+

Rationale: The LEP chosen for use with a laser system must take into account the laser's wavelength and optical density.

Page 8 of 9

In addition to determining that different LEP needs to be implemented, you begin to develop other appropriate recommendations for controls. Using the information you've written on your notepad and the ANSI standards related to laser hazard controls, determine the appropriate controls needed to protect personnel from the laser hazard in the LASIK surgical room.

Which one of the following types of signs should be used outside the surgical room?

B DANGER

Which one of the following is true regarding the use of interlocks with this laser system?

C Interlocks are required.

Which of the following is true regarding the use of LEP with this laser system?

C LEP is required.

Which one of the following is true regarding use of protective barriers and curtains with this laser system?

B Protective barriers and curtains are optional.

Which one of the following is true regarding the operation of this laser system?

C Authorized personnel are required to operate the laser.

Which one of the following is true regarding the education and training of personnel who work with and around the laser system?

C Education and training is mandatory.

Course Glossary

Acronyms

AAR
After Action Report

ACADA
Automatic Chemical Agent Detection Alarm

AFI
Air Force Instruction

AFMIC
Armed Forces Medical Intelligence Center

AFMS
Air Force Medical Service

AFMSA
Air Force Medical Support Agency

AFOSH
Air Force Occupational and Environmental Safety, Fire Prevention and Health

AFRRAD
Air Force Radiation and Radioactive Recycling and Disposal

ALARA
As Low As Reasonably Achievable

AMC
Aerospace Medicine Council

amu
Atomic Mass Unit

AO
Area of Operations

AOC
Area of Concern

AOR
Area of Responsibility

BE
Bioenvironmental Engineering Flight

CBRN
Chemical, Biological, Radiological, Nuclear

CE
Civil Engineering

COA
Course of Action

COC
Contaminant of Concern or Constituent of Concern

CONUS
Continental United States

CSM
Conceptual Site Model

CV
Coefficient of Variability

DIA
Defense Intelligence Agency

DF
Duty Factor

DOD
Department of Defense

DOE
Department of Energy

DOS
Department of State

DOT
Department of Transportation

D_{pel}
Estimated Hazard Distance

DRI
Direct Reading Instruments

EHF
Extremely High Frequency (Occurs between 30 and 300 GHz)

EMR
Electromagnetic Radiation

EPA
Environmental Protection Agency

EPD
Electronic Personal Dosimeters

FPWG
Force Protection Working Group

G_{abs}
Absolute Gain

HF
High Frequency (Occurs between 3 and 30 MHz)

HRA
Health Risk Assessment

HRE
Health Risk Estimate

HRM
Health Risk Management

IATA
International Air Transport Association

IPE
Individual Protection Equipment

LCL
Lower Confidence Limits

LET
Linear Energy Transfer

LF
Low Frequency (Occurs between 30 and 300 kHz)

MAJCOM
Major Command

MEDIC CD
Medical Environmental Disease Intelligence and Countermeasure CD

MIO
Medical Intelligence Officer

MF
Medium Frequency (Occurs between 300 and 3,000 kHz (3MHz))

MOPP
Mission Oriented Protection Posture

MPE
Maximum Permissible Exposure

MSP
Mission Support Plan

NFB
Near-Field Boundary

NGIC
National Ground Intelligence Center

NHZ
Nominal Hazard Zone

NIOSH
National Institute for Occupational Safety and Health

NOHD
Nominal Ocular Hazard Distance

NRC
Nuclear Regulatory Commission

OCONUS
Outside the Continental United States

OEH
Occupational and Environmental Health

OEHSA
Occupational and Environmental Health Site Assessment

OEL
Occupational Exposure Limits

OEL-C
Occupational Exposure Limits-Ceiling

OEL-STEL
Occupational Exposure Limits-Short Term Exposure Limit

OEL-TWA
Occupational Exposure Limits-Time Weighted Average

OH
Occupational Health

ORM
Operational Risk Management

OSHA
Occupational Safety and Health Administration

OSI
Office of Special Investigation

P_{avg}
Average Power

PEL
Permissible Exposure Limit

PH
Public Health

P_p
Peak Power

PPBS
Planning, Programming and Budgeting System

PPE
Personal Protective Equipment

PPM
Parts per million

PRF
Pulse Repetition Frequency

PW
Pulse Width

RFR
Radio Frequency Radiation

RSO
Radiation Safety Officer

S
Main-Beam Power Density

SAR
Specific Absorption Rate

S_{avg}
Power Density Average

SEG
Similar Exposure Group

SHF
Super High Frequency (Occurs between 3 and 30 GHz)

SLM
Sound Level Meter

S_{max}
Maximum Power Density

SPL
Sound Pressure Level

TLD
Thermoluminescent Dosimeters

TWG
Threat Working Group

UHF
Ultra High Frequency (Occurs between 300 and 3,000 MHz)

USACHPPM
United States Army Center for Health Promotion and Preventive Medicine

UTC
Unit Type Code

VA
Vulnerability Assessments

VHF
Very High Frequency (Occurs between 30 and 300 MHz)

VLF
Very Low Frequency (Occurs between 3 and 30 kHz)

Definitions

Absolute Gain (G_{abs})
The ratio of the power that would be required at the input of an ideal isotropic radiator to the power actually supplied to the given antenna, to produce the same radiant intensity in the far-field region.

Action Level
An airborne exposure level that dictates active air monitoring, medical monitoring, and employee training. The Action Level is one-half the Occupational Exposure Limit for time-weighted average (OEL-TWA) exposures, except where 29 CFR 1910 Subpart Z designates a different concentration or where the statistical variability of sample results indicates that a lower fraction of the OEL should be used as the Action Level.

Activity
The number of disintegrations or transformations of radioactive material per unit of time (usually expressed in seconds).

Antenna
The point on an RFR emitter where RFR energy radiates into free space.

Asbestos
A natural material that is made of tiny threads or fibers. The fibers can enter the lungs as a person breathes. Asbestos can cause many diseases, including cancer. Asbestos was used to insulate houses from heat and cold. It has also been used in car brakes and for other purposes. Some old houses still have asbestos in their walls or ceilings.

Asbestosis
A lung disease caused by breathing asbestos fibers over a period of time. The fibers eventually scar the lungs and make breathing difficult. Symptoms are similar to asthma.

Atomic Mass Unit (amu)
Approximately equal to the mass of a proton or a neutron and is used to describe the mass of an atom.

Becquerel (Bq)
The international standard for the unit of measurement for activity.

Breathing Zone
The location where exposure is measured in air sampling. The breathing zone is located forward of the shoulders within 9 inches of the nose and mouth. Breathing zone measurements are taken beneath a welder's helmet or face piece but outside of any respiratory protective devices.

Bremsstrahlung
An interaction that causes a form of x-ray production in which high-speed beta particles penetrate the electron cloud and interact with the nucleus.

Carcinogens
Hazardous materials that stimulate the formation of cancer.

Ceiling Limit (OEL-C)
The limit for an employee's exposure which shall not be exceeded during any part of the work day. If instantaneous monitoring is not feasible, the OEL-C will be evaluated during the worst-case 15-minute exposure period.

Chrysotile
The most common asbestos type. Chrysotile asbestos fibrils may appear crinkled, like permed or damaged hair, under plane-polarized light.

Coefficient of Variation (CV)
For an air sampling method, the CV is the standard deviation of the sampling and analytical error divided by the mean of the sample results. The CV is used to calculate the confidence limits for sampling. OSHA uses the term sampling and analytical error (SAE) to account for the total variation or error in the method.

Compton Scatter
A gamma/x-ray interaction which takes place between a photon and an outer electron where the photon has more energy than the electron can accept, so it imparts only a portion of its energy to the electron.

Conceptual Site Model (CSM)
Articulates the health threats and exposure pathways and begins when data or information is gathered during Predeployment and Baseline Activities.

Confidence Limits
The upper confidence limit (UCL) and lower confidence limit (LCL) are the boundaries for a single sample or a series of samples that have a specified probability (usually 95 percent) of including the true value of the level of exposure.

Controlled Environments
An area where personnel are aware of the potential for RFR exposures associated with their employment or duties.

Counts per minute (cpm)
The amount of radiation detected by an instrument each minute.

Diffuse Reflection
Situations where a laser beam is bounced off a dull or uneven surface that breaks the beam apart.

Disintegration per minute (dpm)
The number of atoms that decay or transform in a given amount of material per minute.

Disintegration per second (dps)
The number of atoms that decay or transform in a given amount of material per second.

Dose
The quantity of radiation absorbed.

Dose Rate
The quantity of radiation absorbed per unit of time.

Duty Factor (DF)
A unit-less number which only applies to pulsed wave systems that describes the ratio of time an RFR emitter is on to the total operating time.

Electromagnetic Radiation (EMR)
Waves of energy that can travel through space and matter.

Electromagnetic Spectrum
The entire frequency range of electromagnetic waves, or wave radiation.

Energy
The ability to do work.

Estimated Hazard Distance (D_{pel})
The distance from the antenna to the point where the power density equals the permissible exposure limit (PEL).

Excitation
Occurs when there is an addition of energy to an atomic system, changing the atom from a “ground” state to an excited state.

Exposure
Exposure occurs when an employee is subjected to a hazardous material through any of these routes: inhalation, ingestion, skin contact, or skin absorption. Airborne exposures are specified as the duration and concentration of hazardous materials measured in the breathing zone of an individual worker without regard for personal protective equipment used by the worker.

Exposure Assessment
An exposure assessment is a process of estimating or calculating potential exposure of a health threat for an individual or population at risk. The assessment includes professional judgment, calculations based on estimates or models, actual measurements, collection and analysis of samples, and statistical evaluation.

Exposure Pathway
Includes a threat and the opportunity for the population to come into contact with the threat.

f
Algebraic express that means, “a function of.”

Fission
The splitting of the nucleus of an atom into nuclei of lighter atoms, accompanied by the release of energy.

Frequency
A value of how often a wavelength cycle occurs in a second.

Gain
The antenna’s ability to concentrate its energy in a certain direction.

Hazardous materials
Materials that pose a hazard and require a Material Safety Data Sheet as defined in FED-STD 313, Federal Standard, Material Safety Data, Transportation Data and Disposal Data for Hazardous Materials Furnished to Governmental Activities.

Health Risk
The health risk equals threat “combined with” vulnerability (health risk = (threat) + (vulnerability)). A health risk is an identified health threat and the vulnerability of the population at risk of coming into contact (i.e., completion of an exposure pathway) with the health threat.

Health Risk Assessment (HRA)
Health risk assessment is the process of identifying and analyzing or evaluating (exposure and toxicity assessments) OEH threats in populations or at locations over time (HRA = f [(health risk) “+” (HRE) “+” (COA)]). The HRA “product” is the validated health threat, qualified by the HRE, and the COA which includes overall mission impact, recommended control options, associated uncertainties, risk mitigation estimate(s), and a cost-benefit analysis if applicable.

Health Risk Communication
Health risk communication is the process of effectively communicating potential health effects, outcomes, and control measures to all stakeholders (i.e., commanders, supervisors, AF personnel, military, families, and the public). It provides detailed information about the HRA and should occur throughout the HRA process.

Health Risk Estimate (HRE)
Health Risk Estimate is the probability and severity of loss from exposure to the health threat. The HRE is a function of probability and severity when either or both increase the Health Risk Estimate increases. The HRE is also referred to as a health risk level.

Health Risk Management (HRM)
Health risk management is a decision-making process to evaluate and select COAs, minimize OEH risks, and maximize benefits for operations and missions. HRM is the health component of the ORM process and health risk management recommendations and decisions are integrated into the commander's ORM decision-making.

Health Threat
A health threat is a potential or actual condition that can cause short or long-term injury, illness, or death to personnel. A health threat can be occupational or environmental in origin; internal or external to the installation; or continuous, intermittent, or transient; and includes enemy capability and intent.

Ionization
Occurs when beta particles interact with nearby atoms causing an electron to be removed, creating an ion pair.

Ionizing Radiation
Radiation which has enough energy to change the atomic structure of matter.

Isotope
Elements with the same number of protons, but a different number of neutrons.

Kinetic Energy
Energy of motion.

Laser
Light amplification by stimulated emission of radiation.

Linear Energy Transfer (LET)
Energy lost by particles along the path through which they are traveling.

Mass
Description of how much matter there is present in an object.

Maximum Permissible Exposure (MPE)
The level of laser radiation to which a person may be exposed without hazardous effects or adverse biological changes in the eyes or skin.

Mesothelioma
Cancer that generally occurs in the chest, abdominal region, and areas surrounding the heart. It is typically associated with exposure to asbestos.

n
Algebraic express that means, "Number of samples."

Nominal Hazard Zone (NHZ)
The area within a laser workplace in which the exposure from direct beam, specular reflection, and diffuse reflection could exceed the Maximum Permissible Exposure (MPE).

Nominal Ocular Hazard Distance (NOHD)
The distance along the laser beam beyond which the exposure is not expected to exceed the appropriate Maximum Permissible Exposure (MPE).

Non-aqueous Phase Liquids (NAPLs)
Non-aqueous phase liquids are liquids that are sparingly soluble in water. Because they do not mix with water, they form a separate phase. For example, oil is an NAPL because it does not mix with water, and oil and water in a glass will separate into two separate phases. NAPLs can be lighter than water (LNAPL) or denser than water (DNAPL). Hydrocarbons, such as oil and gasoline, and chlorinated solvents, such as trichloroethylene, are examples of NAPLs.

Non-ionizing Radiation
Radiation which does not have enough energy to change the atomic structure of matter.

Nuclear Stability
Describes the certain combinations of neutrons and protons within a nucleus of an atom which are required for that atom to be considered stable.

Occupational and Environmental Health Site Assessment (OEHSA)
The key operational health tool for producing data or information used for health risk assessments (HRA) and to satisfy Occupational and Environmental Health (OEH) surveillance requirements.

Occupational Exposure Limit (OEL)
The limit for the airborne concentrations of a specified substance for a specified time. Employees will not be exposed to concentrations greater than the OEL. The term OEL includes all OEL-TWAs, OEL-STELs, OEL-Cs, and acceptable ceiling concentrations, that apply to a specific substance. For each hazardous material, the OELs are the most stringent limits found in the latest edition of the TLV Booklet published annually by the American Conference of Government Industrial Hygienists, in 29 CFR 1910 Subpart Z, and in AFOSH Standards for specific substances. OELs apply to occupational exposures for each individual worker for a single 8-hour work shift except where 29 CFR 1910 Subpart Z allows 40-hour averages. Exposure during work shifts that exceed 8 hours must be adjusted before applying an OEL.

Operational Risk Management (ORM)
A systematic process of identifying hazards, assessing risk, analyzing risk control options and measures, making control decisions, implementing control decisions, accepting residual risks, and supervising/reviewing the activity for effectiveness.

Optical Cavity
The component that houses the laser.

Pair Production
Occurs when a photon disappears in the vicinity of a nucleus, and an electron and positron appear in its place.

Particulate Radiation
Fast-moving atomic or subatomic particles that may be charged positively or negatively or not at all.

Peak Power (P_p)
The maximum power density during the on time for a pulsed wave system.

Permissible Environment
Operational environment in which host country military and law enforcement agencies have control as well as the intent and capability to assist operations that a unit intends to conduct.

Permissible Exposure Limit (PEL)
The value to which an individual may be exposed without exhibiting damaging biological effects and is based on the emitter's frequency.

Photochemical Reaction
A chemical reaction which is induced by the absorption of energy in the form of visible, infrared, or ultraviolet radiation.

Photoelectric Effect
An "all or none" energy loss where gamma rays impart all of their energy into an electron.

Pleural Effusion:
When too much fluid collects between the lining of the lung and the lining of the inside wall of the chest.

Positron
Created when a proton changes into a neutron and a positron because there are too many protons in the n:p ratio.

Potential Energy
Energy of position.

Pulse Repetition Frequency (PRF)
The number of times the signal is on per unit of time.

Pulse Width (PW)
The length of time the signal is on for a pulsed wave system.

Quality Factor (Q)
A dimensionless quantity assigned to each type of radiation that allows doses to be normalized in relation to each other.

Radiation
Energy in the form of waves or moving subatomic particles emitted by an atom or other body as it changes from a higher energy state to a lower energy state.

Radiation Absorbed Dose (RAD)
The amount of radiation absorbed by the tissue.

Radioactive Decay
The spontaneous disintegration or transformation of an atom in an attempt by that atom to reach a stable state.

Radioactive Material (RAM)
Material which contains unstable (radioactive) atoms that give off radiation as they decay or transform.

Radioactivity
The spontaneous emission of matter or energy from the nucleus of an unstable atom.

Radioisotopes
Unstable isotopes that, in an attempt to become a stable atom, emit energy in the form of radiation.

Regulated Area
An area under the supervisor's control where entry and exit are restricted and controlled to prevent exposure to hazards. An area shall be established when a requirement in 29 CFR 1910 or 29 CFR 1926 exists, or when BE determines that employees entering the area might be exposed to a hazard unless access is controlled.

Short Term Exposure Limit (OEL- STEL)
A time-weighted exposure for a 15 minute (or shorter) period which shall not be exceeded during the work day. The definition of STEL is different in 29 CFR 1910.1000 (a) (5) (ii) and in the TLV Booklet. The definition must correspond to the reference being cited. As with other OELs, OEL-STELs are the most stringent limits found in the latest TLV Booklet, in 29 CFR 1910 Subpart Z, and in AFOSH Standards for specific substances.

Short-Term Public Emergency Exposure Guideline (SPEGL)
An acceptable peak concentration for unpredicted, single, short-term emergency exposures of the general public. These limits do not apply to occupational exposures.

Specific Absorption Rate (SAR)
An expression of how much RFR energy is imparted to each kilogram of biological body mass per second. SAR is expressed in units of watts per kilogram (W/kg).

Specular Reflection
Situations where a laser beam is reflected from shiny, mirror-like surfaces.

Spontaneous Fission
Spontaneous fission is a natural mode of decay in which nuclei disintegrate.

Stakeholders
Any individual who is affected by the content of the communication and/or will be making decisions based on the information provided.

Stratigraphy
The layering of rock or ice strata, from which information on succession, age relations, and origin can be deduced.

Threshold Limit Values—(TLVRs)
Exposure guidelines published annually by the American Conference of Governmental Industrial Hygienists (ACGIH) in Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices. TLVRs are employed as OELs when they are more stringent than the OSHA PELs.

Time-Weighted Average (OEL-TWA)
Eight-hour average concentration for which the average is mathematically adjusted for the duration of exposure. The method for calculating OEL-TWAs is shown in 29 CFR 1910.1000 (d) and in the TLV Booklet.

Toxicology Assessment
Process of estimating the human toxicological impact of a specific material based on published and unpublished literature sources and taking into consideration: uptake, metabolism/biotransformation, transport and storage, and excretion including acute (short-term) and chronic (long-term) human health endpoints.

Transmission Line
Carries the RFR signal from the transmitter to the antenna.

Transmitter
The part of an RFR emitter that generates the RFR signal.

Uncontrolled Environments
An area where exposures may be incurred by people who have no knowledge or control of the hazard.

Wavelength
The distance from one peak of a wave to the next peak of a wave.

Appendix

- ANSI Z136.1-2007, American National Standard for Safe Use of Lasers, Table 10, Control Measures for the Seven Laser Classes

Table 10. Control Measures for the Seven Laser Classes

Engineering Control Measures	Classification						
	1	1M	2	2M	3R	3B	4
Protective Housing (4.3.1)	X	X	X	X	X	X	X
Without Protective Housing (4.3.1.1)	LSO shall establish Alternative Controls						
Interlocks on Removable Protective Housings (4.3.2)	∇	∇	∇	∇	∇	X	X
Service Access Panel (4.3.3)	∇	∇	∇	∇	∇	X	X
Key Control (4.3.4)	—	—	—	—	—	•	X
Viewing Windows, Display Screens and Collecting Optics(4.3.5.1)	Assure viewing limited < MPE						
Collecting Optics (4.3.5.2)							
Fully Open Beam Path (4.3.6.1)	—	—	—	—	—	X NHZ	X NHZ
Limited Open Beam Path (4.3.6.2)	—	—	—	—	—	X NHZ	X NHZ
Enclosed Beam Path (4.3.6.3)	None is required if 4.3.1 and 4.3.2 fulfilled						
Remote Interlock Connector (4.3.7)	—	—	—	—	—	•	X
Beam Stop or Attenuator (4.3.8)	—	—	—	—	—	•	X
Activation Warning Systems (4.3.9.4)	—	—	—	—	—	•	X
Indoor Laser Controlled Area (4.3.10)	—	•	—	•	—	X NHZ	X NHZ
Class 3B Indoor Laser Controlled Area (4.3.10.1)	—	—	—	—	—	X	—
Class 4 Laser Controlled Area (4.3.10.2)	—	—	—	—	—	—	X
Outdoor Control Measures (4.3.11)	X	• NHZ	X NHZ	• NHZ	X NHZ	X NHZ	X NHZ
Laser in Navigable Airspace (4.3.11.2)	X	• NHZ	X NHZ	• NHZ	X NHZ	X NHZ	X NHZ
Temporary Laser Controlled Area (4.3.12)	∇ MPE	∇ MPE	∇ MPE	∇ MPE	∇ MPE	—	—
Controlled Operation (4.3.13)	—	—	—	—	—	—	•
Equipment Labels (4.3.14 and 4.7)	X	X	X	X	X	X	X
Laser Area Warning Signs and Activation Warnings (4.3.9)	—	—	—	—	•	X NHZ	X NHZ

LEGEND:
- X Shall
- • Should
- — No requirement
- ∇ Shall if enclosed Class 3B or Class 4
- MPE Shall if MPE is exceeded
- NHZ Nominal Hazard Zone analysis required
- · May apply with use of optical aids

Table 10. Control Measures for the Seven Laser Classes (cont.)

Administrative and Procedural Control Measures	Classification						
	1	1M	2	2M	3R	3B	4
Standard Operating Procedures (4.4.1)	—	—	—	—	—	•	X
Output Emission Limitations (4.4.2)	—	—	—	—	LSO Determination		
Education and Training (4.4.3)	—	•	•	•	•	X	X
Authorized Personnel (4.4.4)	—	•	—	•	—	X	X
Alignment Procedures (4.4.5)	∇	∇	∇	∇	∇	X	X
Protective Equipment (4.6)	—	•	—	•	—	•	X
Spectators (4.4.6)	—	•	—	•	—	•	X
Service Personnel (4.4.7)	∇	∇	∇	∇	∇	X	X
Demonstration with General Public (4.5.1)	—	•	X	•	X	X	X
Laser Optical Fiber Transmission Systems (4.5.2)	MPE	MPE	MPE	MPE	MPE	X	X
Laser Robotic Installations (4.5.3)	—	—	—	—	—	X NHZ	X NHZ
Protective Eyewear (4.6.2)	—	—	—	—	—	•	X
Window Protection (4.6.3)	—	—	—	—	—	X	X NHZ
Protective Barriers and Curtains (4.6.4)	—	—	—	—	—	•	•
Skin Protection (4.6.6)	—	—	—	—	—	X	X NHZ
Other Protective Equipment (4.6.7)	Use may be required						
Warning Signs and Labels (4.7) (Design Requirements)	—	—	•	•	•	X NHZ	X NHZ
Service Personnel (4.4.7)	LSO Determination						
Laser System Modifications (4.1.2)	LSO Determination						

LEGEND:
- X Shall
- • Should
- — No requirement
- ∇ Shall if enclosed Class 3B or Class 4
- MPE Shall if MPE is exceeded
- NHZ Nominal Hazard Zone analysis required
- • May apply with use of optical aids

Table 11a. Summary of Area Warning Signs

Clause	Title	Classification				Required Statement or Comment
		2	3R	3B	4	
3.5.1	Personnel	X	X	X	X	Some individuals may be unable to read or understand signs
4.3.9.1	Warning Sign Posting	-	X	X	X	Specifies which sign required Caution, Danger, Notice
4.3.9.2	Laser Warning Sign Purpose	-	X	X	X	States the four purposes of warning signs
4.3.9.3	Warning Sign Non-Beam Hazard	X	X	X	X	Must follow requirements of other appropriate documents
4.3.9.4.1	Audible Warning Devices	-	-	X	X	Audible warning should be required for Class 3B and shall for Class 4
4.3.9.4.2	Visible Warning Devices	-	-	X	X	Visible warning should be required for Class 3B and shall for Class 4
4.7.1	Design of Signs		X	X	X	Per ANSI Z535 requirements
4.7.2.1.1	Laser Symbol		X	X	X	Laser sun burst required on all signs per ANSI
4.7.2.1.2	International Laser Symbol					International symbol as specified in IEC 60825-1 is acceptable
4.7.2.2	Safety Alert Symbol		X	X	X	The alert symbol is required on all Caution & Danger Signs
4.7.3.1	Signal Word "Danger"		X	X	X	Specifies when to use "Danger" word and format
4.7.3.2	Signal Word "Caution"		X			Specifies when to use "Caution" word and format
4.7.3.3	Signal Word "Notice"		X	X	X	Specifies when to use "Notice" word and format
4.7.4	Pertinent Sign Information		X	X	X	Specifies the location of words on signs
4.7.4.3	Location of Signs		X	X	X	Specifies location of signs

Note: Signs and labels prepared in accordance with previous revisions of this standard are considered to fulfill the requirement of the standard.