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Rochester Institute of Technology's Laser Safety Manual

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Rochester Institute of Technology’s Laser Safety Manual

By Joseph Whitney

Graduate Thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Environmental, Health & Safety Management

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April 14, 2006

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Date: 2/14/2006 Signature of Author: ___________________________ Joseph R. Whitney
Rochester Institute of Technology Laser Safety Manual

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Abstract

Rochester Institute of Technology’s Laser Safety Manual and Training Guide have been created as a recommended safety manual and training guide to help laser users work with lasers and laser systems in a safe manner. Standard operating procedures and protocols have been provided in order to assist the laser user in complying with Local, State, and Federal regulations.

The immense number and variation of lasers that are available makes laser safety a necessity. This manual contains guidelines that enable the laser user to identify areas of concern and apply corrective actions as needed. This manual addresses a wide array of information that is neither exhaustive nor definitive. The Laser Safety Officer (LSO) and the Laser Supervisor (LS) shall act as consultants and instructors to the laser user in appropriate use and operation of the laser or laser system as potential hazardous situations arise.

Because Federal regulations relating to workplace safety only apply to employees, Rochester Institute of Technology has adapted its Laser Safety Manual to the American National Standards Institute for the Safe Use of Lasers (ANSI Z136.1-2000). It is Rochester Institute of Technology’s belief that the Radiation Safety Committee, Laser Safety Officer, Laser Supervisor, Faculty and Staff shall make all efforts to ensure that laser users are provided with the necessary information, materials, and training that will enable them to work with lasers and laser systems in a safe manner.
1.0 Introduction

This manual describes a recommended laser safety program for Rochester Institute of Technology (RIT). The purpose of RIT's laser safety program is to ensure the safe use of lasers and laser systems in RIT's research and instructional laboratories. This program requires that all lasers and laser systems must be operated in accordance with the American National Standards Institute (ANSI) Z136.1-2000 and any federal regulations that may apply. All lasers can cause injury if misused. The primary objective of RIT's laser safety program is to ensure that all personnel, students, guests, and property are protected from hazards associated with lasers and laser systems. These safety standards, regulations, and policies will be the basis for RIT's Safety Manual: Eye and face protection (29 CFR 1910.132); Lockout/Tagout (29 CFR 1910.147); Respiratory Protection (29 CFR 1910.134); OSHA's General Duty Clause (Section 5); Performance Standards for Light-Emitting Products (21CFR1040.10); ANSI Z136.1-2000 Safe Use of Lasers; and ANSI Z136.1-2005 Safe Use of Lasers in Educational Facilities.

The increasing use of lasers in our world requires more individuals to become familiar with the potential hazards associated with the misuse of lasers and laser systems. Lasers are used in many applications in our everyday life and laser safety is an important part of all laser applications. Lasers are used in communications, hospitals, industry, military, and in research laboratories. The associated hazards of lasers and laser systems have been addressed by way of regulations, standards and policies. These regulations, standards and policies that relate to laser safety are different for different parties involved, i.e., manufacturer, user, safety officer, incidental personnel, safety committee, etc.
2.0 Laser Fundamentals

2.1 Scientific Principles of Lasers

2.1.1 Definition

The word laser is an acronym for Light Amplification by Stimulated Emission of Radiation. Lasers are devices that produce and amplify light. This light is pure in color and can be extremely intense. This intensity can be generated beyond the visible range from the infrared to the x-ray range.

2.1.2 The Basics of an Atom

Our Universe is composed of approximately 100 different atoms. These atoms bond together with one another in infinite combinations. They are the building blocks of matter. All matter is composed of atoms. An atom consists of protons, neutrons, and electrons. Protons are positively charged particles, neutrons are neutrally charged particles and electrons are negatively charged particles.

2.1.3 Atomic Structure

In the early 20th century Ernest Rutherford and Niels Bohr developed a way of thinking about the structure of an atom. The Rutherford-Bohr model of the atom was much like our solar system (Figure 1). The nucleus (sun) is orbited by the planets (electrons). (HSF)
This is a classic (Rutherford-Bohr) example of what an atom looks like:

![Diagram of the atom](image)

Figure 1: Rutherford-Bohr Model of the Atom

This atom is comprised of a nucleus (protons and neutrons) and the orbiting electrons.

2.1.4 Atom Structure

**Nucleus**

The nucleus of an atom contains small particles called protons and neutrons

**Proton**

Protons are positively charged particles that are constituents of the nucleus of all atoms of an element. The elements atomic number is directly related to the number of protons an element has.

**Neutron**

Neutrons are particles with no electrical charge that are constituents of the nucleus of all atoms of an element (hydrogen is the exception). Neutrons have the ability to exist in a
free state, giving them great penetrating capabilities that are able to yield large amounts of damage to living tissue.

*Electrons*

Electrons are particles of matter that have negative electric charge. They are the constituents of the atom that orbit the nucleus. Electrons are capable of having many different energy levels. These different levels of energy are referred to as states of excitation. When energy is applied to an atom, the electron can be excited from what is known as the ground state to various excited states, depending on the amount of energy that is applied to the atom.

2.1.5 Electron Energy Levels

*Electron in the Ground State*

An electron normally occupies itself in its lowest state of energy, the ground state (Figure 2).

![Ground State](image)

Figure 2: Electron in the Ground State
Ionized Electron

The electron can be excited to many different energy levels. The ionization energy is the amount of energy required to remove the electron from the atom (Figure 3). The electron will continue to be bound to the nucleus of the atom until this ionization energy is reached.

![An ionized electron](Figure 3: Electron Excited from the Ground State to an Excited State)

When energy is applied to the atom, the electron will jump from the ground state (lowest energy level) to an excited state, farther away from the nucleus (Figure 4).

![Ground State](Excited State)

Figure 4: Absorption of a Photon
2.1.6 Light Energy

The Bohr model of an atom depicts the orbit of an electron around the nucleus. Each orbital requires a specific amount of energy to move from a lower energy orbital to a higher energy orbital. Electrons can change from one energy state to another by absorption or emission. (HSF)

Absorption

There are two primary ways that electrons can absorb energy. (1) Energy of a photon is transferred directly to an orbital electron where the increase in the energy of the electron causes it to jump from a lower energy orbital to a higher energy orbital (excited state). (2) Accelerating the electron within an electric field is another means of exciting an electron. This energy is supplied by electrons colliding with one another. Both types of excitation move electrons from a lower energy orbital to a higher energy orbital. (HSF)

Emission

Atomic structures tend to exist in the lowest energy levels possible. After an electron has moved from a lower to a higher energy orbital, it will want to return to the ground state. When the electron returns to the ground state, it will release energy as heat or as a photon. If a photon is released by an atom, it will have a total energy that is exactly equal to the difference in energy between the higher energy orbital and the lower energy orbital. (HSF)
Emission of a Photon

Because electrons prefer to be in the ground state they will emit a photon that will have a total energy that is exactly equal to the difference in energy between the higher energy orbital and the lower energy orbital (Figure 5).

![Diagram of excited state and ground state with photon emission](image)

Figure 5: Emission of a Photon

2.1.7 Laser Light

Laser light is very different from normal light. Laser light has the following properties:

1. The light released is monochromatic. It contains one specific wavelength of light (one specific color). The wavelength of light is determined by the amount of energy released when the electron drops to a lower orbit.
2. The light released is coherent. It is “organized” -- each photon moves in step with the others. This means that all of the photons have wave fronts that launch in unison.
3. The light is very directional. A laser light has a very tight beam and is very strong and concentrated. (HSF)
Atom-Light Interactions

When light of the right color hits an atom, it will cause the electron to jump from a lower energy level to a higher energy level (orbital). Since electrons prefer to be located in the ground state, they fall back to the lower level and emit a photon of the same color in some random direction. (HSF)

Stimulated Emission

In 1917, Einstein postulated that a photon released from an excited atom could, upon interacting with a second, similarly excited atom, trigger the second atom into de-exciting itself with the release of another photon. The photon released by the second atom would be identical in frequency, energy, direction, and phase with the triggering photon, and the triggering photon would continue on its way, unchanged. Where there was one photon now there are two. These two photons could then proceed to trigger more through the process of stimulated emission. If an appropriate medium contains a great many excited atoms and de-excitation occurs only by spontaneous emission, the light output will be random and approximately equal in all directions. The process of stimulated emission, however, can cause an amplification of the number of photons traveling in a particular direction. (OSHA PUB 8) The direction of the photons is controlled by placing mirrors at each end of the optical cavity, enabling the photons to travel in the same direction at a higher concentration. As the concentration increases, stimulated emission of radiation occurs and if the amplification is sufficient, laser light is created.
**Population Inversion**

Stimulated emission will not produce sufficient amplification of light unless the ratio of atoms in the excited state to atoms in the ground state is sufficient. As the concentration of atoms in the excited state increases, the probability of stimulated emission occurring also increases. Normally, electrons reside in the ground state, the lowest energy level. When the electrons are excited, they fill the upper energy or high energy orbitals, leaving the lower energy orbitals depopulated. When the concentration of electrons in the upper energy level becomes greater than the concentration of electrons in the lower energy level, population inversion occurs.

2.1.8 Components of a Laser

A laser consists of a "pumping" system, a lasing medium and an optical cavity (Figure 6). The laser material must have a metastable state in which the atoms or molecules can be trapped after receiving energy from the pumping system. Each of these laser components is described below:

![Figure 6: Components of a Laser](image-url)
**Optical Cavity**

The optical cavity (Resonator) contains the media to be excited. The photons are redirected with mirrors back along the same general path. This is where the lasing action occurs.

**Pumping System**

The pumping system pumps energy (electrical, thermal, or optical) into the atomic population of the laser medium in order to create a state of population inversion.

**Laser Medium**

The laser medium can be a solid, dye, gas, or semiconductor. The medium is the material that is used to emit the laser light. Generally, the laser is named after the medium being employed.

**Solid State**

Solid state lasers consist of a lasing material that is distributed in a solid matrix. Solid state lasers are rugged, simple to maintain, and capable of generating high powers. Solid state lasers emit energy in the infrared range of the electromagnetic spectrum. Examples of solid state lasers include the ruby or neodymium-YAG (yttrium aluminum garnet) lasers.

**Gas**

Gas lasers use a single gas or a mixture of gases for the active medium. Because they are rugged, reliable, and relatively inexpensive, gas lasers are the most widely used laser in
existence. Helium-neon (HeNe), carbon dioxide (CO$_2$), and argon ion (Ar) are the most commonly used gas lasers. Gas lasers such as helium and helium-neon emit energy in visible and far-infrared regions of the electromagnetic spectrum.

**Excimer**

Excimer lasers (excited and dimers) use reactive halogen gases such as chlorine and fluorine mixed with noble gases such as krypton, argon, or xenon to produce excited dimers. When electrically stimulated, dimers are produced. As the dimer is lased, energy is emitted in the ultraviolet range of the electromagnetic spectrum. Common excimer lasers include argon-fluoride, xenon-chloride, xenon-fluoride, and krypton-fluoride.

**Dye**

Dye lasers use a laser medium composed of complex organic dyes in a liquid solution. Use of varying concentrations of dyes enables this medium to emit energy in and near the visible spectrum.

**Semiconductor**

Semiconductor lasers (diode lasers) are not solid-state lasers. These lasers are composed of two layers of semiconductor material that are packed tightly together. Generally, these electronic devices are very small and can produce only low levels of power.

See Appendix G for a summary of more common laser types and their corresponding wavelengths.
2.2. Laser Classifications

Laser and laser systems are classified according to the potential hazards associated with accessible radiation during normal operation that may cause biological damage to the eye and skin. Lasers shall be appropriately labeled according to the levels of accessible radiation to provide warning to laser users. Additionally, laser hazard classification defines appropriate control measures and medical surveillance.

The American National Standards ANSI Z136.1-2000 and the U.S. Food and Drug Administration Center for Devices and Radiological Health (CDRH) have established classification systems for lasers and laser systems according to their capability of causing biological damage to the eye and/or skin. The LSO and/or LS of the laser/laser system will apply the standards from ANSI Z136.1-2000 and ANSI Z136.1-2005 to classify the lasers and evaluate the related hazards.

The following three aspects of the application of a laser or laser system influence the total hazard evaluation and the application of appropriate controls:

1) The laser or laser system’s capability of injuring personnel

2) The environment in which the laser or laser system is used

3) The personnel who may use the laser, laser system, or the personnel that will be exposed to laser radiation.
2.2.1. Class 1 Lasers and Laser Systems

Any laser, or laser system containing a laser, that cannot emit accessible laser radiation levels in excess of the applicable Class 1 Accessible Emission Limit (AEL) for any emission duration within the maximum duration inherent in the design or intended use of the laser or laser system is a Class 1 laser or laser system during operation and is exempt from all control measures or other forms of surveillance with the exception of applicable requirements for embedded lasers. The maximum exposure duration is assumed to be no more than 30,000 s except for infrared systems not intended to be viewed (> 0.7 nm), 100 s shall be used. The exemption strictly applies to emitted laser radiation hazards and not to other potential hazards. (ANSI Z136.1-2000)

Class I levels of laser radiation are not considered to be hazardous.

2.2.2. Class 2 Lasers and Laser Systems

Class 2 lasers and laser systems are visible (0.4 to 0.7nm) CW and repetitive-pulse lasers and laser systems which can emit accessible radiant energy exceeding the appropriate Class 1 AEL for the maximum duration inherent in the design or intended use of the laser or laser system, but not exceeding the Class 1 AEL for any applicable pulse (emission) duration < 0.25 s and not exceeding an average radiant power of 1mW. (ANSI Z136.1-2000)

Class 2 levels of laser radiation are considered to be a chronic viewing hazard.
2.2.3. Class 3 Lasers and Laser Systems (3a and 3b)

*Class 3a Lasers and Laser Systems*

Class 3a lasers and laser systems produce moderate levels of visible or invisible laser radiation and require more stringent controls than Class 2 lasers. The CW output power of a Class 3a visible laser is between 1 to 5 mW and the normal aversion response is generally sufficient to prevent injury from inadvertently viewing the output with the unaided eye. However, the use of collecting optics, e.g., binoculars, can produce retinal irradiances that are considered capable of causing injury. Optically aided eye exposure to Class 3a lasers which produce ultraviolet or infrared emissions may not be perceived by the eye at the end of injury. For such lasers, the Class 3a accessible emission limit does not rely upon the normal aversion response, but rather on the fact that the eye does not fixate on the beam long enough to cause injury. (ANSI Z136.1-2000)

Class 3a Lasers are considered to be a hazard under extended viewing conditions, or when viewed with collecting optics.

*Class 3b Lasers and Laser Systems*

Class 3b lasers may produce visible or invisible emissions. The output power of CW visible and infrared Class 3b lasers range from 5 to 500 mW. They are considered medium power lasers and are capable of producing eye injury when viewed directly or with optics, even if viewed momentarily. For visible Class 3b lasers, the normal aversion response (0.25 s) does not prevent injury. Class 3b lasers do not usually produce a
hazardous diffuse reflection or fire hazard. At the upper end of the Class 3b range skin burns may be possible. (ANSI Z136.1-2000)

Class 3b levels of laser radiation are considered to be an acute hazard to the skin and eyes from direct radiation.

2.2.4. Class 4 Lasers and Laser Systems

Class 4 lasers are visible or invisible lasers emitting radiation capable of causing injury to the eye and skin as well as producing dangerous specular and diffuse reflections. They can also produce a fire hazard. (ANSI Z136.1-2000)

Class 4 levels of laser radiation are considered to be an acute hazard to the skin and eyes from direct and scattered radiation.

See Appendix B, C, and D for a summary of hazards for laser classifications.

2.3. Laser Hazards

2.3.1. Beam Hazards

Laser radiation of sufficient intensity and exposure over time can cause irreversible damage to the skin and eye of man (OSHA PUB 8). Thermal hazards represent the most common causes of laser induced tissue damage. In the thermal process, the tissue proteins
are denatured via the increase in temperature that follows the absorption of laser energy.

The thermal damage process is generally associated with lasers operating at exposure times greater than 10 microseconds and in the wavelength region from the near ultraviolet to the far infrared (0.315 - 103 nm). (OSHA PUB 8)

2.3.2. Biological Effects of the Laser Beam

Eye Injury

A laser is an ideal point source of intense light because of its high degree of beam collimation. Theoretically, a laser beam of sufficient power can generate retinal intensities at magnitudes that exceed conventional light sources and, in some cases, direct viewing of the sun. These retinal intensities can result in permanent blindness.

Thermal Injury

Thermal hazards represent the most common causes of laser induced tissue damage. In the thermal process, the tissue proteins are denatured via the increase in temperature that follows the absorption of laser energy.

The thermal damage process (burns) is generally associated with lasers operating at exposure times greater than 10 microseconds and in the wavelength region from the near ultraviolet to the far infrared (0.315 μm-103 μm). Tissue damage may also be caused by thermally induced acoustic waves following exposures to sub-microsecond laser exposures. (OSHA PUB 8)
The principal thermal effects of laser exposure depend upon the following factors (OSHA PUB 8):

1) The absorption and scattering coefficients of the tissues at the laser wavelength.
2) Irradiance or radiant exposure of the laser beam
3) Duration of the exposure and pulse repetition characteristics
4) Extent of the local vascular flow
5) Size of the area irradiated

2.3.3. Other

Other damage mechanisms have also been demonstrated for other specific wavelength ranges and/or exposure times. For example, photochemical reactions are the principal cause of threshold level tissue damage following exposures to either actinic ultraviolet radiation (0.200 µm-0.315 µm) for any exposure time or "blue light" visible radiation (0.400 µm-0.550 µm) when exposures are greater than 10 seconds.

To the skin, UV-A (0.315 µm-0.400 µm) can cause hyperpigmentation and erythema. Exposure in the UV-B range is most injurious to skin. In addition to thermal injury caused by ultraviolet energy, there is the possibility of radiation carcinogenesis from UV-B (0.280 nm - 0.315 nm) either directly on DNA or from effects on potential carcinogenic intracellular viruses.

Exposure in the shorter UV-C (0.200 µm-0.280 µm) and the longer UV-A ranges seems less harmful to human skin. The shorter wavelengths are absorbed in the outer dead
layers of the epidermis (stratum corneum) and the longer wavelengths have an initial pigment-darkening effect followed by erythema if there is exposure to excessive levels.

These biological effects are summarized in Table 1.

The hazards associated with skin exposure are of less importance than eye hazards; however, with the expanding use of higher-power laser systems, particularly ultraviolet lasers, the unprotected skin of personnel may be exposed to extremely hazardous levels of the beam power if used in an unenclosed system design. (OSHA Technical Manual)
Table 1: Summary of Biological Effects

<table>
<thead>
<tr>
<th>Photobiological spectral domain</th>
<th>Eye effects</th>
<th>Skin effects</th>
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<tbody>
<tr>
<td><strong>Ultraviolet C (0.200-0.280 μm)</strong></td>
<td>Photokeratitis</td>
<td>Erythema (sunburn)</td>
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<tr>
<td></td>
<td></td>
<td>Skin cancer</td>
</tr>
<tr>
<td><strong>Ultraviolet B (0.280-315 μm)</strong></td>
<td>Photokeratitis</td>
<td>Accelerated skin aging</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Increased pigmentation</td>
</tr>
<tr>
<td><strong>Ultraviolet A (0.315-0.400 μm)</strong></td>
<td>Photochemical</td>
<td>Pigment darkening</td>
</tr>
<tr>
<td></td>
<td>UV cataract</td>
<td>Skin burn</td>
</tr>
<tr>
<td><strong>Visible (0.400-0.780 μm)</strong></td>
<td>Photochemical</td>
<td>Photosensitive reactions</td>
</tr>
<tr>
<td></td>
<td>and thermal</td>
<td>Skin burn</td>
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<td></td>
<td>retinal injury</td>
<td></td>
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<tr>
<td><strong>Infrared A (0.780-1.400 μm)</strong></td>
<td>Cataract, retinal burns</td>
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<tr>
<td><strong>Infrared B (1.400-3.00 μm)</strong></td>
<td>Corneal burn</td>
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<td></td>
<td>IR cataract</td>
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<td><strong>Infrared C (3.00-1000 μm)</strong></td>
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<td>Skin burn</td>
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Optical Fibers

Optical fibers can be used to transmit laser energy to remote or otherwise inaccessible locations. Laser transmission systems that employ optical cables shall be considered enclosed systems with the optical fiber sheath forming part of the enclosure. The beam emerging from an optical fiber usually diverges rapidly. Depending on the power, at close range the output from the end of a fiber may be hazardous. Therefore, the LSO shall determine the conditions under which a hazard could exist. As a general rule, the beam emerging from the fiber should be treated with the same caution as the direct beam from a laser. (ANSI Z136.1-2005)

2.3.4. Nominal Hazard Zone

NHZ Definition

The Nominal Hazard Zone (NHZ) is the zone where the level of reflected, scattered, or direct radiation during normal operation is in excess of the Maximum Permissible Exposure limit (MPE), the level of radiation to which a person may be exposed without hazardous effect or adverse biological changes in the eye or skin. See Appendix E and F for a summary of common MPE’s. The NHZ can be a valuable tool for assessing zone hazards and implementing controls for Class 3b and Class 4 open-beam lasers and laser systems. Where open beams are required, determining the NHZ can be used to define the area where there is a possibility for a potentially hazardous exposure. Additionally, the NHZ can determine a boundary around the laser or laser system that is non-hazardous, or below the MPE level.
The NHZ boundary may be defined by direct beams, diffusely scattered beams, and beams that may be transmitted from fiber optics. The perimeter around the NHZ contains the MPE exposure levels from any specific laser installation configuration.

The NHZ evaluation's purpose is to define the hazardous area where controls measures are required. The MPE value is required in all NHZ calculations by the ANSI Z 136 standard. Table 2 gives NHZ distance values for various lasers. The following factors are required in NHZ computations:

1) Laser power or energy output
2) Beam diameter
3) Beam divergence
4) Pulse repetition frequency (prf)
5) Wavelength
6) Beam optics and beam path
7) Maximum anticipated exposure duration.
<table>
<thead>
<tr>
<th>Laser type</th>
<th>Exposure criteria</th>
<th>Diffuse</th>
<th>Lens-on-laser</th>
<th>Direct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nd:YAG</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 Watt</td>
<td>8 hours</td>
<td>1.4</td>
<td>11.3</td>
<td>1410</td>
</tr>
<tr>
<td>1.064 µm</td>
<td>10 seconds</td>
<td>0.8</td>
<td>6.3</td>
<td>792</td>
</tr>
<tr>
<td>CO₂</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>500 Watt</td>
<td>8 hours</td>
<td>0.4</td>
<td>5.3</td>
<td>309</td>
</tr>
<tr>
<td>10.6 µm</td>
<td>10 seconds</td>
<td>0.4</td>
<td>5.3</td>
<td>390</td>
</tr>
<tr>
<td>Argon</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.0 Watt</td>
<td>8 hours</td>
<td>12.6</td>
<td>1.7 x 10³</td>
<td>25.2 x 10³</td>
</tr>
<tr>
<td>0.488 µm</td>
<td>0.25 seconds</td>
<td>0.25</td>
<td>33.3</td>
<td>240</td>
</tr>
</tbody>
</table>

Laser criteria used for NHZ distance calculations:

<table>
<thead>
<tr>
<th>Laser parameter</th>
<th>Nd-YAG</th>
<th>CO₂</th>
<th>Argon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelength (µm)</td>
<td>1.064</td>
<td>10.6</td>
<td>0.488</td>
</tr>
<tr>
<td>Beam power (Watts)</td>
<td>100.0</td>
<td>500.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Beam divergence (mrad)</td>
<td>2.0</td>
<td>2.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Beam size at aperture (mm)</td>
<td>2.0</td>
<td>20.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Beam size at lens (mm)</td>
<td>6.3</td>
<td>30.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Lens focal length (mm)</td>
<td>25.4</td>
<td>200.0</td>
<td>200.0</td>
</tr>
<tr>
<td>MPE for 8 hours (w/cm²)</td>
<td>1.6 x 10³</td>
<td>1.0 x 10⁵</td>
<td>1.0</td>
</tr>
<tr>
<td>MPE for 10 seconds (w/cm²)</td>
<td>1.0 x 10⁵</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>MPE for 0.25 second (w/cm²)</td>
<td>---</td>
<td>---</td>
<td>2.5 x 10³</td>
</tr>
</tbody>
</table>

Source: ANSI Z 136.1
2.4. Non-Beam Hazards

Non-beam hazards are hazards that do not result from direct human exposure to a laser beam. Because non-beam hazards are different from beam hazards, they require different control measures. All non-beam hazards must be evaluated by the LSO or the LSO may employ the LS to evaluate these hazards.

2.4.1. Electrical Hazards

Electrical safety requirements are imposed upon laser devices, systems, and those who work with them, by the Occupational Safety and Health Administration (OSHA), the National Electrical Code (NFPA 70), and related state and local laws and regulations. These requirements govern equipment connection to the electrical utilization system, electrical protection parameters, and specific safety training. These requirements must be observed with all laser installations. The following potential electrical problems are problems in general that have been identified as common findings in industrial and educational facilities during laser facility audits:

1) Uncovered electrical terminals.
2) Improperly insulated electrical terminals.
3) Hidden “power-up” warning lights.
4) Lack of personnel trained in current cardiopulmonary resuscitation practices, or lack of refresher training.
5) “Buddy system” or equivalent safety measure not being practiced during maintenance and service.
6) Failure to properly discharge and ground capacitors.
7) Non earth-grounded or improperly grounded laser equipment.

8) Non-adherence to the OSHA lock-out standard (29CFR 1910.147).

9) Excessive wires and cables on floor that create fall or slip hazards. (ANZI 136.1-2005)

2.4.2. Laser-Generated Air Contaminants (LGAC)

Laser generated air contaminants (LGAC) may be generated when certain Class 3b and Class 4 laser beams interact with matter. The quantity, composition, and chemical complexity of the LGAC depend greatly upon target material, cover gas, and the beam irradiance. The LSO shall ensure that the following industrial hygiene aspects of exposure to LGAC are addressed and that appropriate measures are effected.

1) Control measures

2) Exhaust Ventilation

3) Respiratory Protection

4) Process Isolation (ANZI 136.1-2005)

2.4.3. Collateral Radiation

Collateral radiation is radiation other than radiation from the primary laser beam that may be produced by system components such as power supplies, plasma tubes, and discharge lamps. Collateral radiation may be in the form of plasma, x radiation, radio frequency radiation, including UV, visible, IR, radio, and microwave.
2.4.4. X Radiation

X radiation may be generated by electronic components of the laser system. Examples include high-voltage vacuum tubes and laser-metal induced plasmas. X radiation that emanates from laser power supplies and components should be investigated, i.e., intensity and characteristics, and controlled according to local, state, and federal codes and regulations.

2.4.5. Ultraviolet (UV) and Visible Radiation

Collateral UV emitted from laser discharge tubes and pump lamps shall be suitably shielded so that personnel exposures are maintained within the exposure limits specified by the ACGIH. UV radiation may cause photo dermatitis as a result of exposure to some industrial chemicals or medications. (ANZI 136.1-2000)

Radiofrequencies (RF)

Some lasers contain RF excited components, e.g., plasma tubes and Q-switches. Appropriate protection guides for RF exposure is found in the latest version of the IEEE C95.1-1999. (ANZI 136.1-2000)

Plasma Radiation

Plasma emissions created during laser-material interaction processes may contain sufficient UV and blue light (0.18 to 0.55um) to raise concern about long-term viewing without protection. Studies have shown that the integrated blue-light irradiance levels are
much higher for CO2 than for Nd:YAG lasers. Also welding events yield higher plume radiation levels than cutting events. (ANZI 136.1-2000)

2.4.6. Fire Hazards

Class 4 laser beams can result in potential fire hazards if enclosure materials are likely to be exposed to irradiances exceeding 10 W.cm-2 or beam powers exceeding 0.5 W. Under some situations where flammable compounds or substances exist, it is possible that fires can be initiated by Class 3 lasers. Flame retardant materials must be used wherever applicable with all laser applications. (ANZI 136.1-2000)

Laser barriers such as curtains can be used to block the laser beam from exiting the work area during certain operations. Laser barriers offer a range of protection. However, they are not able to withstand high irradiance levels and may be damaged within a few seconds. Damage may include smoke, open fire, or penetration. Users should refer to the NFPA Code #115 for further information on controlling laser fires.

Operators of Class 4 lasers should be aware of the ability of unprotected wire insulation and plastic tubing to catch on fire from intense reflected or scattered beams, particularly from lasers operating at invisible wavelengths. (ANZI 136.1-2000)

2.4.7. Explosion Hazards

High-pressure arc lamps, filament lamps, and capacitor banks in laser equipment shall be enclosed in housings which can withstand the maximum explosive pressure resulting
from component disintegration. The laser target and elements of the optical train which may shatter during laser operation shall also be enclosed or equivalently protected to prevent injury to operators and observers. Explosive reactions of chemical laser reactants or other laser gases may be a concern in some cases. (ANZI 136.1-2000)

2.4.8. Compressed Gases at Rochester Institute of Technology

Compressed gases are used on RIT’s campus every day for numerous activities and operations. These gases are used for operating equipment used in teaching and research activities, as well as for maintaining the Institute’s buildings and facilities. Kept under high pressure, compressed gas containers may rupture and violently release energy if they are not handled properly or are damaged in any way, and could become a projectile hazard. In addition, compressed gas containers may contain gases that are flammable, combustible, explosive, corrosive, or poisonous and may therefore cause additional health hazards if the gases are released. (RIT’s Compressed Gas Safety Manual) Many hazardous gases such as chlorine, fluorine, hydrogen chloride, and hydrogen fluoride, are used in laser applications. Safely handling compressed gases should be controlled through use of training and standard operating procedures. Some potential safety concerns related to compressed gas use include:

1) Working with a free-standing cylinder not isolated from personnel.
2) Inability to protect open cylinders (regulator disconnected) from atmosphere and contaminants.
3) No remote shutoff valve or provisions for purging gas before disconnect or reconnect.

4) Labeled hazardous gas cylinders not maintained in appropriate exhausted enclosures.

5) Gases of different categories (toxics, corrosives, flammable, oxidizers, inerts, high pressure, and cryogenics) not stored separately in accordance with OSHA regulations.

2.4.9. Laser Dyes and Solvents

Laser dyes are complex fluorescent organic compounds which, when in solution with certain solvents, form a lasing medium for dye lasers. Certain dyes are highly toxic or carcinogenic. Since these dyes frequently need to be changed, special care must be taken when handling solutions, preparing solutions, and operating dye lasers. An MSDS for dye compounds shall be available to all appropriate workers.

The use of dimethylsulfoxide (DMSO) as a solvent for cyanine dyes in dye lasers should be discontinued if possible. DMSO aids in the transport of dyes through the skin and into the blood stream. If another solvent cannot be found, low permeability gloves should be worn by personnel any time a situation arises where contact with the solvent may occur.

Dye lasers containing at least 100 milliliters of flammable liquids shall be in conformance with the provisions of the NFPA (NFPA 30 and 45), and the NEC (Article 500 – Hazardous (classified) Locations). Laser dyes shall be prepared in a laboratory
fume hood. Dye pumps and reservoirs should be placed in secondary containment vessels to minimize leakage and spills in conformance with NFPA 115. (ANZI 136.1-2000)

2.4.10. Noise

Noise levels from certain lasers, such as pulsed excimer lasers, may be of such intensity that noise control may be necessary. Consult the US Department of Labor, Occupational Safety and Health Administration Regulations and the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs). (ANZI 136.1-2000)

2.4.11. Waste Disposal

Proper waste disposal of contaminated laser related material, such as flue and smoke filters, organic dyes, and solvent solutions shall be handled in conformance with appropriate local, state, and federal agencies and RIT waste disposal procedures. (ANZI 136.1-2000)

2.4.12. Limited Work Space

Many laser systems are installed in areas that are limited by space. This limited space can be problematic when working near or around high electrical equipment. The laser system must be installed in an area that allows the operator to maneuver without obstacles and slip and trip hazards. Special care must be taken when more than one laser is being operated at the same time in the same vicinity. If laser-generated air contaminants are present in a limited work space, one or more of the following may be required:
1) Local exhaust
2) Mechanical ventilation
3) Respiratory protection
4) Ergonomics

Arm, hand, and wrist injuries may result from repetitive motions that occur during the use of laser products. The LSO shall be aware of any ergonomic hazards that may be present in laser system designs or that are created by neglecting ergonomic principles in laser system designs. Laser users should contact the LSO for any ergonomic concerns in laser use areas.

3.0 RIT Laser Safety Program Organization

RIT's Laser Safety Organization has been established to ensure that laser/laser system users, Institute employees, students, and visitors are protected from hazards associated with lasers. The Laser Safety Program Organization will be composed of the following: Radiation Safety Committee (RSC), Laser Safety Officer (LSO), Radiation Safety Officer (RSO), Laser Supervisor (LS), Laser user. Members of RIT's Laser Safety Organization can be found in Appendix I.

3.1 Radiation Safety Committee (RSC)

3.1.1 Committee Membership and Rationale
A Radiation Safety Committee (RSC) has been established at RIT to give continual recognition to policies, problems, and potential hazards related to ionizing and non-ionizing radiation at the Institute. The structure and membership of the RSC is described in RIT’s Radiation Safety Manual. The Laser Safety Officer serves as a member of the Radiation Safety Committee. The Radiation Safety Committee along with the Radiation Safety Officer and Laser Safety Officer will serve to address any laser safety issues on campus.

3.1.2. Committee Responsibilities

The use of lasers at R.I.T is governed through the Radiation Safety Committee (RSC). This committee is a group of faculty and staff that establish policy and regulations for the use of radiation sources as well as oversee all aspects of radiation safety. The following items are the laser safety responsibilities of the RSC.

- Ensure that all individuals who work with or in the vicinity of lasers and laser systems have sufficient training and experience to enable them to perform their duties safely and in accordance with federal and state regulations.
- Be familiar with all pertinent New York State Department of Safety and Health (NYSDOSH) regulations.
- Be familiar with all pertinent Occupational Health and Safety Administration (OSHA) regulations.
3.1.3. Duties

The Radiation Safety Committee shall review all applicable laser safety standards that apply to laser safety at RIT and meet as often as necessary to conduct its business, but not less than twice in each academic year. Written records of all Radiation Safety Committee meetings, actions, recommendations, and decisions will be maintained as outlined in the Radiation Safety Manual.

The LSO, Risk Management Team, and RSC shall review the laser safety program at least annually to determine that all activities are being conducted safely and in accordance with New York State Department of Safety and Health regulations and recommend remedial action to correct any deficiencies identified in the laser safety program. The LSO is responsible for the following:

1) In conjunction with the Risk Management Team, the LSO will perform a first line review of all laser use requests and will bring Class 3b and Class 4 laser requests to the attention of the RSC for comment and/or review.

2) Annual report to the RSC regarding laser issues.

3) Respond to accidents and perform investigations.

4) Annual review and update to laser inventory.

5) Inspection of laser-use areas.

6) Ensure that all use of lasers and laser systems is conducted in a safe manner and in accordance with federal and state regulations.
7) Review the training and experience of all individuals who use lasers and laser systems and determine that their qualifications are sufficient to enable them to perform their duties safely and in accordance with federal and state regulations.

8) Establish and maintain policies, procedures, and guidance for the control of laser hazards.

9) Verify that adequate safety control measures (Appendix L) are in place before approving operation of Class 3b or Class 4 laser operation. The Laser Safety Officer may grant temporary approval for operation if the Laser Safety Officer verifies that there are adequate laser safety control measures in place. Final approval will be determined by the Radiation Safety Committee.

3.2. Laser Safety Officer (LSO)

Rochester Institute of Technology’s Laser Safety Officer (Appendix I) has the authority to monitor and enforce the control of laser hazards and to evaluate and specify measures to control laser hazards on campus. The Laser Safety Officer has the authority to suspend, restrict, and terminate the operation of a laser project if it is deemed that the laser hazard controls are inadequate. The LSO shall establish a program to ensure that all incidental personnel whose duties may require them to work in the vicinity of Class 3b or Class 4 lasers and laser systems are properly instructed in laser safety. The LSO shall prescribe special conditions and monitoring, such as medical surveillance, when required.
3.2.1. Specific Responsibilities of the LSO

Classification

The LSO shall be responsible for effecting the classification or verification of the classification of Class 3b and Class 4 lasers and laser systems used under the LSO’s jurisdiction. Unmodified lasers or laser systems classified by the manufacturer in accordance with the Federal Laser Product Performance Standard may be considered as fulfilling all classification requirements of this standard. In cases where the laser or laser system classification may change due to the addition or deletion of engineering controls, the laser or laser system shall be classified in accordance with the prescribed in ANSI Z136.1-2000.

Hazard Evaluation

The LSO shall be responsible for the hazard evaluation of laser work areas, including the establishment of Nominal Hazard Zones (NHZs) and standard operating procedures (SOPs) as prescribed in ANSI Z136.1-2000. The hazard evaluation shall consider the level of maturity of and ability of each person who is to be permitted within the NHZ. The LSO shall inspect all teaching and research set-ups involving the use of lasers and shall have the responsibility to immediately bring a potentially hazardous condition to the attention of the responsible faculty or staff in order to discontinue, cancel, or postpone a demonstration or research project until the condition has been addressed.
Control Measures

The LSO shall be responsible for assuring that the prescribed control measures (Appendix L) are in effect, recommending or approving substitute or alternate control measures when the primary ones are not feasible or practical, and periodically auditing the functionality of those control measures in use. This shall include, but not be limited to, such actions as establishing NHZ, approving standard operating procedures (SOPs), avoiding unnecessary or duplicate controls, selecting alternate controls, conducting periodic facility and equipment audits, and training.

Procedural Approvals

The LSO shall approve SOPs, alignment procedures, and other procedures that may be part of the requirements for administrative and procedural controls. The LSO shall ensure that each person (staff and students) working with Class 3b and Class 4 lasers receives a copy of the approved procedures and/or rules of conduct for general laser use.

Protective Equipment

The LSO shall recommend or approve protective equipment, i.e., eyewear, clothing, barriers, screens, etc., as may be required to assure personal safety. The LSO shall assure that protective equipment is inspected and audited periodically to ensure proper working order.
Signs and Labels

The LSO shall approve the wording of area signs and equipment labels. The LSO shall be responsible for appropriate wording and labels on lasers or laser systems that are constructed at the institution or on any altered commercially manufactured device that emits laser radiation.

Facility and Equipment

The LSO shall approve laser installation facilities and laser equipment prior to use. This also applies to modification of existing facilities or equipment.

Safety Features Audits

The LSO shall be responsible for the periodic examination of the safety features of laser equipment, installations and laser facilities to ensure their safe operation and usage. This examination shall occur bi-annually and/or each time a laser system or installation has been modified using the laser safety audit form found in Appendix M.

Training

The LSO shall ensure that adequate safety education and training is provided to staff and students and others using Class 3b and Class 4 lasers and laser systems. The LSO shall maintain records for each of these persons, indicating that appropriate training has been provided. Laser safety training requirements are outlined in Appendix N.
Medical Surveillance

The LSO shall identify the personnel that require medical surveillance. These personnel shall include but are not restricted to administration, faculty, staff, and students who work with Class 3b and Class 4 lasers or laser systems. The LSO shall ensure that applicable medical examinations are scheduled and performed and shall maintain the appropriate records to that effect. The requirements for medical surveillance are listed in Section 4.8: Medical Surveillance.

Accidents

On notification of a known or suspected accident resulting from operation of a laser or laser system, the LSO shall effect an investigation of the accident and initiate appropriate action. This may include the preparation of reports to appropriate agencies. Refer to Section 4.7.3: Violation Levels.

Consultative Services

The LSO will provide consultative services on laser hazard evaluation and controls and on personnel training programs. Such evaluations will include electrical and other non-radiation hazards of lasers.

Authority

The LSO will have the authority to suspend, restrict, or terminate the operation of a laser or laser system if he or she deems that laser hazard controls are inadequate.
**Records**

The LSO will ensure that the necessary records required by applicable government regulations are maintained. The LSO will also submit to the appropriate medical officer the names of each individual that will be monitored under the medical surveillance program. The LSO will ensure that the appropriate records are maintained indicating that applicable medical examinations have been scheduled and performed and that appropriate training has been provided.

**Surveys and Inspections**

The LSO will survey by inspection, as considered necessary, all areas where laser equipment is used. This survey will occur bi-annually and/or each time a laser or laser system is modified using RIT’s Laser Safety Audit Form in Appendix M. The LSO will also accompany regulatory agency equipment inspectors, such as those representing OSHA, FDA/CDRH, state agencies, etc., and document any discrepancies noted. The LSO will ensure that corrective action is taken where required.

**Approval of Laser Systems Operations**

Approval of a laser or laser system for operation will be given only if the LSO is satisfied that laser hazard control measures are adequate. These include SOPs for maintenance and service operations within enclosed systems, and operation procedures for Class 3b or 4 systems. The procedures will include adequate consideration to assure safety from electrical hazards.
3.3. Specific Responsibilities of the Laser Supervisor

For each laser and/or laser system at RIT, regardless of the laser’s classification, there will be one person (faculty or staff) assigned as the Laser Supervisor. The Laser Supervisor will be designated at the time the laser or laser system is registered with the LSO. The Laser Supervisor will be responsible for each of the following items for their laser or laser system.

Training

The supervisor must attend laser safety training. The supervisor will be knowledgeable of the requirements for laser safety, the potential hazards and associated control measures for all laser and laser systems, education and all policies, practices and procedures pertaining to laser safety at locations under the supervisor’s authority.

Indoctrination

The supervisor will be responsible for ensuring training on laser hazards and their control to all personnel who may work with lasers that are operated within the supervisor’s jurisdiction. In addition, the supervisor is responsible for implementation and enforcement of all safety recommendations in RIT’s Laser Safety Manual.

Laser Hazard Control

The supervisor will not permit the operation of a laser unless there is adequate control of laser hazards to employees, visitors, and the general public.
Individuals Scheduled to work with lasers

The supervisor will submit the names of individuals scheduled to work with lasers to the LSO and, in addition, will submit information as requested by the LSO for medical surveillance scheduling and training completion.

Reporting of known or suspected accidents

When the supervisor knows of or suspects an accident resulting from a laser operated under his or her authority, the supervisor will immediately notify the LSO or other designated authority regarding the incident.

Medical Attention

Supervisors must immediately notify Campus Safety at x333 (or 475-3333) in the event of an exposure to a Class 3b or 4 laser beam or reflection or any other accident or exposure involving a laser. If necessary, the supervisor will assist in obtaining appropriate medical attention for any user involved in a laser accident.

Approval of Laser System Operation

The supervisor will not permit operation of a new or modified laser under his or her authority without the approval of the LSO.
Approval of Planned Installation

The supervisor will make sure that plans for laser installations or modifications of installations are submitted to the LSO for approval well in advance of the desired installation or modification date.

Operating Procedures

For class 3b or class 4 lasers and laser systems, the supervisor will be responsible for developing SOP’s and ensuring that they are provided to users of such lasers.

Labeling & Signage

The LS shall ensure that all lasers in the laboratory or research area are properly classified and labeled. The LS shall ensure that all necessary warning signs are displayed in their appropriate areas.

3.4. Specific Responsibilities of Laser Users

Laser users shall include operators, technicians, engineers, maintenance and service personnel, and any other personnel working with or around lasers. Laser/laser system users are responsible for:

Training

Laser users shall attend laser safety training and be familiar with any safety hazards that may be present when working on or near lasers. Laser users shall be trained to follow
standard operating procedures for each laser/laser system that will be operated. Laser users at Rochester Institute of Technology shall pass the laser safety quiz before operating lasers on campus. The laser safety quiz is located in Appendix O.

**Authorizations**

Users will not energize or work with or near a laser/laser system unless authorized to do so by the supervisor of that laser.

**Compliance**

Users will comply with safety rules and procedures prescribed by the supervisor and the LSO. The user will be familiar with all standard operating procedures (SOP’s) and inform the supervisor of any deviations from the SOP’s.

**Accident Reporting**

When a user operating a laser/laser system knows or suspects that an accident has occurred involving that laser, or a laser operated by any other employee, and that such an accident has caused an injury or could potentially have caused an injury, he or she will immediately inform the supervisor, who is responsible for informing the LSO. If the supervisor is not available, the user will notify the LSO directly.
4.0 Rochester Institute of Technology Laser Safety Procedures

4.1 Laser Registration and Inventory

General

All lasers at Rochester Institute of Technology are required to be registered with the Laser Safety Officer prior to use so that they can be listed in RIT’s Laser Inventory, and appropriate control measures can be put into place. RIT’s current laser inventory can be found in Appendix J.

Registration

To register a laser, complete the laser registration form (Appendix K) and submit it to the LSO. The Laser Safety Officer will review the completed laser registration form and upon approval, inform the Laser Supervisor of the safety requirements for the class of laser being registered. The laser registration shall be signed by the Laser Safety Officer and the Chair of the Radiation Safety Committee.

A Laser Supervisor shall be assigned for each laser and responsibility shall fall upon that supervisor for all others who use that laser. The LS who holds the registration of the laser is responsible for compliance with all safety precautions that are stated in the Laser Safety Manual and SOP’s for each individual laser/laser system. All laser facilities containing Class 3b and Class 4 lasers and laser systems shall be audited on a periodic basis by staff from the Radiation Safety Committee and the LSO. Reports will be sent to the Laser Supervisor with deficiencies noted. The deficiencies shall be addressed by the
LS in a timely manner. The LS is responsible for informing the LSO of all users that operate Class 3b and Class 4 lasers or laser systems under the direct supervision of the LS. The LS is also responsible for ensuring that the laser user is qualified to operate the laser or laser system and the LS must ensure that all eye exams have been completed, if required for the specified laser or laser system. Additionally, the LS is responsible for informing the LSO of any changes to lasers or laser systems including placement and location of lasers.

4.2. Training & Standard Operating Procedures (SOP’s)

4.2.1. General

Only qualified and trained individuals are permitted to operate lasers or laser systems at RIT. Each individual who operates a laser shall receive general laser safety training provided by the LSO. The Laser Supervisor shall provide system specific operational training on the Standard Operating Procedures (SOP’s) for the Laser Supervisor’s registered laser area. If the laser is used in a laboratory where there may be other hazards, general laboratory safety training will also be required for the laser users. Laser safety training requirements are outlined in Appendix N.

The LSO will provide general Laser Safety Training to insure that all faculty, staff and students assigned to service, maintain, install, adjust, and operate laser equipment are appropriately qualified and trained. The training will include the general topics listed below, and where possible, will be tailored to address the specific lasers to be used by the individuals being trained:
1) Fundamentals of lasers

2) Biological effects of laser radiation

3) Laser classifications

4) Hazards

5) Controls

6) Medical Surveillance

7) Personal protective equipment

8) Emergency response

Training attendance and training records will be tracked and retained by the LSO in the EHS Department files.

System specific operational training will be provided by the Laser Supervisor for each area. This training, which can be either hands-on training or taught in a classroom setting, will include the following:


2) Detailed review and demonstration of standard operating procedures

3) Review and identification of hazards

4) Review and identification of controls

5) Review of appropriate PPE for each laser application

6) Review of emergency response procedures
A training certification form, Appendix P, shall be signed by each attendee and submitted to the LSO.

4.2.2. Recommended Laser Safety Training Requirements

Laser Safety Officer Training: A comprehensive multi-day course which covers all the key aspects of laser safety and an in-depth review of the appropriate standards, OSHA requirements, and needs for state and local compliance, as appropriate. The Laser Safety Officer will maintain this training.

4.2.3. Update Training Requirements

Update training requirements have been shown to be appropriate, especially for research and service personnel where beam alignment is a frequent work requirement. For example, one published account by an individual who lost the sight of one eye when protective eyewear was not used concluded: "But more important than the actual event is the idea that this incident could have been avoided. Don't let it happen to you or a co-worker. Take time to assess safety conditions, and do it again in 6 months or a year; additional hazards arise in an ever-changing research environment. Safety deserves your thoughtful considerations, now, before your accident." (ANSI Z136.1-2005)

4.2.4. Standard Operating Procedures

One of the more important of the administrative and procedural controls is the written Standard Operating Procedure (SOP).
The SOP must be documented and submitted by the LS with each new Class 3b or Class 4 laser registration to the LSO for approval. For each new use or application of the laser, the LS must submit revised SOP’s to the LSO for approval prior to beginning the application. An SOP Template is available in Appendix R. SOPs are not required for classroom use of Class 1, Class 2, or Class 3a lasers or laser systems. All laser experiments and demonstrations shall be approved by the Laser Supervisor in charge of the class or project and by the LSO. An SOP shall be developed for each experiment or demonstration employing the use of Class 3b and Class 4 lasers and the Laser Supervisor shall be responsible for the implementation of these SOPs.

The LSO should require and approve written SOPs for operation, maintenance, and service for all educational research projects, laser teaching experiments, laser demonstrations, and science fair projects using Class 3b lasers or laser systems. The LSO shall require and approve written SOPs for operation, maintenance, and service for all educational research projects using Class 4 lasers or laser systems. The users should ensure that suitable and simplified operating instructions are available for Class 2 and Class 3a lasers. All procedures and instructions shall be maintained with the laser equipment for reference.

The key to developing an effective SOP is the involvement of those individuals who operate, maintain and service the equipment under guidance of the LSO. Most laser equipment comes with instructions for safe operation by the manufacturers; however,
sometimes the instructions are not well suited to a specific application due to special use conditions. SOPs and controls shall include:

1) Designation of the NHZ for all Class 3b and Class 4 lasers by the LSO

2) Appropriate means for separating one laser or laser system from another being used at the same time shall be provided, e.g., partitions, curtains, beam stops or interlocks, as well as a prescribed method for moving between areas during the course of a laboratory session.

3) A thorough discussion of alignment procedures and possible hazards before carrying out an actual alignment in either the laboratory, classroom or multi-use facility. All participants occupying areas where the MPEs may be exceeded shall use protective equipment. A temporary laser-controlled area shall be established during alignment.

4) Directions to perform laser demonstrations using Class 3b or Class 4 lasers with the smallest groups of students possible and in controlled areas. Care should be taken to ensure that students remain in a given teaching area in a multi-use facility until specifically asked to move on to another teaching area. Provisions should be made in the event that a demonstration must be stopped for any reason to allow students to leave the environment of either a sectioned portion or the total multi-use facility.
5) Preparation of customized SOPs for demonstrations or laboratory experiments that
differ from the usual laser activities already covered by an existing SOP. Since there are
many possible permutations of lasers or laser systems in a multi-use facility, and students
may be working with lasers for the first time in an educational or research situation, it is
unlikely that one SOP could cover the use of every potential combination of lasers or
laser systems. The LSO should assist in preparing such SOPs.

4.3. Control Measures

4.3.1. General

Control measures shall be implemented to minimize the possibility of exposure to the eye
and skin to hazardous levels of laser radiation and to minimize other hazards associated
with laser devices during operation, maintenance, and service.

There are four basic categories of controls useful in laser environments. These are
engineering controls, personal protective equipment, administrative and procedural
controls, and special controls. The controls to be reviewed here are based upon the
recommendations of the ANSI Z 136.1 standard and are found in Appendix L.

Important in all controls is the distinction between the functions of operation,
maintenance, and service. First, laser systems are classified on the basis of level of the
laser radiation accessible during operation. Maintenance is defined as those tasks
specified in the user instructions for assuring the performance of the product and may
include items such as routine cleaning or replenishment of expendables. Service functions are usually performed with far less frequency than maintenance functions (e.g., replacing the laser resonator mirrors or repair of faulty components) and often require access to the laser beam by those performing the service functions. The safety procedures required for such beam access during service functions should be clearly delineated in the laser product's service manual.

For all uses of lasers and laser systems it is recommended that the minimum laser radiation required for the application be used. It is also recommended that the laser beam height be maintained at a level other than the normal position of the eye of a person in the standing or seated position.

4.3.2. Laser Safety Officer (LSO).

The LSO has the authority to monitor and enforce the control of laser hazards and effect the knowledgeable evaluation and control of laser hazards. The LSO administers the overall laser safety program where the duties include, but are not limited to, items such as confirming the classification of lasers, doing the NHZ evaluation, assuring that the proper control measures (Appendix L) are in place and approving substitute controls, approving standard operating procedures (SOP's), recommending and/or approving eye wear and other protective equipment, specifying appropriate signs and labels, approving overall facility controls, providing the proper laser safety training as needed, conducting medical surveillance, and designating the laser and incidental personnel categories.
The LSO should receive detailed training including laser fundamentals, laser bioeffects, exposure limits, classifications, NHZ computations, control measures (including area controls, eye wear, barriers, etc.), and medical surveillance requirements.

4.3.3. Laser Controlled Area.

When the entire beam path from a Class 3b or Class 4 laser is not sufficiently enclosed and/or baffled to ensure that radiation exposures will not exceed the MPE, a "laser-controlled area" is required. During periods of service, a controlled area may be established on a temporary basis. The controlled area will encompass the NHZ. Controls required for the different laser class installations are as follows:

**Posting with Appropriate Laser Warning Signs**

Class 3a (beam irradiance 2.5 mW/cm²), Class 3b and Class 4 lasers: Require the ANSI DANGER sign format: white background, red laser symbol with black outline and black lettering. Note that under ANSI Z 136.1 criteria, area posting is required only for Class 3b and Class 4 lasers.

Class 2 or Class 3a areas (if area warning is deemed unnecessary by the LSO): All signs and labels associated with these lasers (when beam irradiance for Class 3a does not exceed 2.5 mW/cm²) use the ANSI CAUTION format: yellow background, black symbol and letters.
During times of service and other times when a temporary laser-controlled area is established, an ANSI NOTICE sign format is required: white background, red laser symbol with blue field and black lettering. This sign is posted only during the time when service is in progress. Examples of area warning signs and logotype designs are given in Appendix Q.

*Transmission from Indoor Controlled Area*

The beams shall not, under any circumstances, be transmitted from an indoor laser-controlled area unless for specific purposes (such as testing). In such cases, the operator and the LSO must assure that the beam path is limited to controlled air space.

The following general laser controls will be required for all Class 4 lasers and may be required by the LSO for any class 3b laser:

1) Supervision directly by an individual knowledgeable in laser safety.
2) Entry of any noninvolved personnel requires approval.
3) A beam stop of an appropriate material must be used to terminate all potentially hazardous beams.
4) Use of diffusely reflecting materials near the beam, where appropriate.
5) Appropriate laser protective eye wear must be provided to and worn by all personnel within the laser controlled area.
6) The beam path of the laser must be located and secured above or below eye level for any standing or seated position in the facility.
7) All windows, doorways, open portals, etc., of an enclosed facility should be covered or restricted to reduce any escaping laser beams below appropriate ocular MPE level.

8) Require storage or disabling of lasers when not in use.

In addition, there are specific controls required at the entryway to a Class 4 laser controlled area. These can be summarized as follows:

1) All personnel entering a Class 4 area shall be adequately trained and provided proper laser protective eye wear.

2) All personnel shall follow all applicable administrative and procedural controls.

3) All Class 4 area and entryway controls shall allow rapid entrance and exit under all conditions.

4) The controlled area shall have a clearly marked "Panic Button" (nonlockable disconnect switch) that allows rapid deactivation of the laser.

Class 4 areas also require some form of area and entryway controls. The ANSI Z 136 Standard provides four options that allow the LSO to provide an entryway control suited for the installation. The LSO will work with the Laser Supervisor to determine which option is best suited for each laser use area. The options include:
1) Nondefeatable Entryway Controls

A nondefeatable control, such as a magnetic switch built into the entryway door, which cuts the beam off when the door is opened, is one option. In this case, training is required only for those persons who regularly work in the laser area.

2) Defeatable Entryway Controls.

Defeatable controls may be used at an entryway, for example, during long-term testing in a laser area. In this case the controls may be temporarily made inactive if it is clearly evident that there is no hazard at the point of entry. Training is required for all personnel who may frequently require entry into the area.

Such defeatable controls shall be designed to allow both rapid egress by the laser personnel at all times and admittance to the laser controlled area in an emergency condition. A readily accessible "panic button" or control/disconnect switch shall be available for deactivating the laser under such emergency conditions.

Under conditions where the entire beam path is not completely enclosed, access to the laser-controlled area shall be limited only to persons wearing proper laser protective eye wear when the laser is capable of emitting a beam. In this case, all other optical paths (for example, windows) from the facility shall be covered or restricted in such a way as to reduce the transmitted intensity of the laser radiation to levels at or below the MPE for direct irradiation of the eye.
3) **Procedural Entryway Controls**

A blocking barrier, screen, or curtain that can block or filter the laser beam at the entryway may be used inside the controlled area to prevent the laser light from exiting the area at levels above the applicable MPE level. In this case, a warning light or sound is required outside the entryway that operates when the laser is energized and operating. All personnel who work in the facility shall be appropriately trained.

4) **Entryway Warning Systems**

In order to safely operate a Class 4 laser or laser system, a laser warning system shall be installed as described:

i) A laser activation warning light assembly shall be installed outside the entrance to each laser room facility containing a Class 4 laser or laser system.

In lieu of a blinking entryway warning, the entryway light assembly may alternatively be interfaced to the laser in such a manner that a light will indicate when the laser is not operational (high voltage off) and by an additional light when the laser is powered up (high voltage applied) but not operating and by an additional (flashing) light when the laser is operating.

ii) A laser warning sign shall be posted both inside and outside the laser-controlled area.

4.3.4. **Classroom Demonstrations**

Classroom demonstrations in open areas in unstructured classes or in situations where the students are not well regulated shall be designed in accordance with the guidelines for
laser demonstrations involving the general public. Classroom demonstrations shall use the lowest power necessary to demonstrate the phenomena under discussion. Class 1 and Class 2 lasers shall be used whenever possible. Class 3 and Class 4 lasers shall only be used when their increased power or energy is necessary. Unless the point of a demonstration can only be accomplished with the invisible radiation, lower power visible lasers (400 nm to 700nm) should be used. Special care shall be taken to avoid direct exposure and exposure to diffuse (when applicable) and specular reflections under these circumstances. Classrooms in which Class 3b or Class 4 lasers are used shall conform to the controls in Appendix L. Lasers or laser systems used in demonstrations shall not be pointed at the audience or instructor. The beam shall terminate at a beam stop that can withstand the maximum power that the laser can produce. The beam stop shall not produce accessible scattered radiation in excess of the MPE for the worst-case viewing situation.

4.3.5. Laser Controlled Areas in Colleges and Universities

Lecture Halls
Lasers used in lecture halls shall be limited to the lowest output power (and lowest class) needed for the demonstration. The direct beam as well as specular and diffuse reflections from Class 4 lasers can be hazardous and should only be used in lecture hall demonstrations if there is no alternative. In addition, direct or diffusely scattered ultraviolet radiation can create a skin hazard, and the direct beam may present a fire
The instructor shall be familiar with the control measures (Appendix L) in this manual and Section 4 of ANSI Z136.1-2000.

**Multi-Use Laser Facility**

The use of a variety of lasers, laser systems or lasers of different wavelengths within a given area increases the potential risk for laser accidents. A systematic procedure shall be followed to characterize the NHZ of each laser or laser system.

The interactive hazard potential in these kinds of environments coupled with the relative inexperience of the personnel involved necessitates a thorough hazard evaluation. Only personnel trained in laser safety, optical engineering or physics are permitted to perform the detailed hazard evaluation computations.

**Laser Pointers**

If a Class 3a laser pointer is used in the classroom for a demonstration or experiment, the following basic safety rules apply:

1) Do not point the laser at any individual
2) Do not directly view the beam or its specular (mirror-like) reflection
3) The lowest possible power should be used, never more than 5mW
4) Remove the batteries when the laser pointer is not in use
Administrative and Procedural Controls

Administrative and procedural controls are methods or instructions that specify rules, or work practices, or both, which implement or supplement engineering controls and which may specify the use of personal protective equipment. These controls apply to Class 2, Class 3a, Class 3b, and Class 4 lasers or laser systems. The Laser Supervisor is responsible for designating and documenting these controls. The Laser Safety Officer shall ensure that these controls are in place during the laser safety audit.

Output Emission Limitations

The LSO shall have the authority to reduce accessible emission levels used in the operation or maintenance of any Class 3a, Class 3b, or Class 4 laser or laser system, if in the judgment of the LSO those levels are considered excessive for the designated application.

Authorized Personnel

It is crucial that only authorized personnel shall operate, maintain and service Class 3b and Class 4 lasers or laser systems in educational settings. This extends to enclosed Class 3b and Class 4 laser systems if such operation, maintenance and service could permit access to levels that exceed the applicable MPE.

Alignment Procedures

The majority of laser accidents occur during alignment procedures. Written SOPs shall specify the alignment procedures. Such SOPs are recommended for Class 3b laser and
laser systems and mandatory for Class 4 lasers or laser systems. The alignment of lower class lasers or laser systems shall be performed in such a manner that any reflection could not expose the eye to levels exceeding the applicable MPE.

**Protective Equipment**

Protective equipment includes eyewear, barriers, windows, clothing, gloves, and other devices. When the potential for exposure to Class 3b or Class 4 laser radiation exists, protective equipment may be required when other controls are inadequate to preclude exposure to laser radiation in excess of the applicable MPE. The LSO shall be consulted in choosing the most appropriate protective equipment for the operation.

**Laser Protective Barriers and Curtains**

When possible, a blocking barrier, screen, or curtain should be utilized inside a controlled area to block or filter laser radiation from exiting at levels exceeding the applicable MPE. Barriers or curtains of different materials/composition may be required to provide adequate protection in areas where multiple lasers are used.

**Spectators**

For Class 3b or Class 4 laser operations, spectators should not be permitted in the laser controlled area. In the educational facility environment, the use of a laser may be strictly for spectator viewing. In these instances spectators may be allowed in the laser controlled area if:

1) Appropriate protective measures are implemented
2) Appropriate approval has been obtained and supervision enforced
3) Control procedures have been explained and the spectators understand the degree of any hazard

*Service Personnel*

The LSO shall require that service personnel have the education and safety training commensurate with the class of laser or laser system they are servicing.

*Other Protective Equipment*

Respirators, additional local exhaust ventilation, fire extinguishers, etc. may be required whenever engineering controls are inadequate.

*Protective Equipment*

Protective equipment for laser safety generally means eye protection in the form of goggles or spectacles, clothing, and barriers and other devices designed for laser protection.

*Laser Protective Eyewear and Clothing*

Eye-protection devices designed to protect against radiation from a specific laser system shall be used when engineering controls are inadequate to eliminate the possibility of potentially hazardous eye exposure (i.e., whenever levels of accessible emission exceed the appropriate MPE levels.) This generally applies only to Class 3b and Class 4 lasers.
All laser eyewear shall be clearly labeled with OD values and wavelengths for which protection is afforded.

Skin protection can best be achieved through engineering controls. If the potential exists for damaging skin exposure, particularly for ultraviolet lasers (0.200-0.400 m), then skin covers and or sun-screen creams are recommended. For the hands, gloves will provide some protection against laser radiation. Tightly woven fabrics and opaque gloves provide the best protection. A laboratory jacket or coat can provide protection for the arms. For Class 4 lasers, flame-resistant materials may be best.

In general, other controls should serve as primary protection rather than depending on employees to use protective eye wear. Many accidents have occurred when eye wear was available but not worn. This may be because laser protective eye wear is often dark, uncomfortable to wear, and limits vision.

*Laser Barriers and Protective Curtains*

Area control can be effected in some cases using special barriers specifically designed to withstand either direct or diffusely scattered beams. The barrier will be described with a barrier threshold limit (BTL): the beam will penetrate the barrier only after some specified exposure time, typically 60 seconds. The barrier is located at a distance from the laser source so that the BTL is not exceeded in the worst-case exposure scenario.
Currently available laser barriers exhibit BTL's ranging from 10 to 350 W/cm² for different laser wavelengths and power levels. An analysis conducted in a manner similar to the NHZ evaluations described previously can establish the recommended barrier type and installation distances for a given laser. It is essential that the barrier also not support combustion or be itself consumed by flames during or following a laser exposure.

**Engineering Controls**

Engineering controls are normally designed and built into the laser equipment to provide for safety. In most instances, these will be included on the equipment (provided by the laser manufacturer) as part of the "performance requirements" mandated by the FLPPS. Specifics on some of the more important engineering controls recommended in the ANSI Z 136.1 standard are detailed as follows:

**Protective Housing**

A laser shall have an enclosure around it that limits access to the laser beam or radiation at or below the applicable MPE level. A protective housing is required for all classes of lasers except, of course, at the beam aperture. In some cases, the walls of a properly enclosed room area can be considered as the protective housing for an open beam laser. Such a "walk-in" enclosure can also be a Class1 laser provided that controls preclude operation with personnel within the room.
Absence of Protective Housings

In some circumstances, such as research projects or electro-optic training, the use of a laser or laser system without the protective housing may be necessary. In this case the LSO shall effect a hazard analysis and ensure that the appropriate controls are implemented. These controls may include access restrictions, eye protection, area controls, barriers, curtains, and beam stops, electrical and chemical protection, and administrative procedural controls including education and training.

Interlocks on Removable Protective Housings

Protective housings that enclose Class 3b or Class 4 lasers or laser systems shall be provided with an interlock system that is activated when the protective housing is opened during operation and maintenance. The interlock shall cause the immediate shutdown, reduction of power, or the interruption of the accessible beam through some other means.

Master Switch Control

A Class 3b laser or laser system should be provided with a master switch. A Class 4 laser or laser system shall be provided with a master switch. This master switch shall be operated by a key or by a coded access. When disabled (key or code removed), the laser cannot be operated. Only authorized system operators are to be permitted access to the key or code.
**Optical Viewing System Safety**

Interlocks, filters, or attenuators are to be incorporated in conjunction with beam shutters when optical viewing systems such as telescopes, microscopes, viewing ports, or screens are used to view the beam or beam-reflection area. For example, an electrical interlock could prevent laser system operation when a beam shutter is removed from the optical system viewing path. Such optical filter interlocks are required for all except Class 1 lasers.

**Viewing Portals and Display Screens**

All viewing portals and display screens (windows) included as an integral part of Class 2, Class 3a, Class 3b, or Class 4 laser or laser system shall incorporate a suitable means to maintain the laser radiation at the viewing position a or below the appropriate MPE for all conditions of operation, training and maintenance.

**Collecting Optics (All Classes)**

All collecting optics intended for viewing use with a laser or laser system shall incorporate suitable means to maintain the laser radiation exiting the collecting optics to levels at or below the appropriate MPE under all conditions of operation or maintenance.

**Beam Paths (Class 3b or Class 4)**

Control of the laser beam path shall be the responsibility of the LSO.
**Totally Open Beam Path (Class 3b or Class 4)**

In applications of Class 3b or Class 4 lasers or laser systems where the entire beam path is unenclosed, a laser hazard analysis shall be affected by the LSO to establish the NHZ. In classrooms or research laboratories the entire room may be considered the NHZ, in which case the entire room shall be a laser controlled area.

**Limited Accessibility**

In Class 3b or Class 4 laser or laser systems where the beam path is confined by design to significantly limit accessibility to the open beam, the controls outlined in this manual and those in Section 4 of the ANSI Z136.1-2000 standard must be followed.

**Enclosed Beams**

In laser or laser system applications where the entire beam path is enclosed, and all requirements of a Class 1 laser or laser system are met, no further controls are required for normal operations.

**Beam Stop or Attenuator**

A Class 3b or Class 4 laser or laser system should be provided with a permanently attached beam stop or attenuator.
Emission Delay (Class 4)

For Class 4 lasers or laser systems, the warning system shall be activated for a sufficient time prior to emissions of the laser radiation to allow appropriate action to be taken to avoid exposure to laser radiation.

Indoor Laser Controlled Area (Class 3b or Class 4)

A laser controlled area shall be established and adequate controls shall be implemented.

Outdoor Controls (Class 3b or Class 4)

A Class 3b or Class 4 laser or laser system used outdoors shall meet the laser safety requirements set forth in ANSI Z136.1-2000, Section 4 and ANSI Z136.6.

Temporary Laser Controlled Area

When removal of panels or protective housings, overriding protective interlocks, or when entry into the NHZ becomes necessary, e.g., for training or service, and when the accessible laser radiation may exceed the applicable MPE, a temporary laser controlled area shall be established. Although a temporary laser controlled area will not have the built-in protective features as defined for laser controlled area, all safety requirements for all personnel, both within and outside this area shall be provided. A notice sign shall be posted outside the temporary laser controlled area to warn of the potential hazard.

Remote Firing and Monitoring (Class 4)

Class 4 laser or laser systems should be monitored and operated from remote locations whenever feasible and the appropriate controls shall apply. When a laser is operated by
remote control, television monitoring, or filtered viewing windows should be used to observe the laser activity. Use of lenses, microscopes, telescopes, and other optical instruments in conjunction with the laser may also require filters.

*Laser Activation Warning System (Class 3b or Class 4)*

An alarm (audible), a warning light (visible through protective eyewear) or a verbal countdown should be used with a Class 3b or Class 4 laser or laser system.

*Service Access Panels*

The ANSI Z 136.1 standard requires that any portion of the protective housing that permits direct access to an embedded Class 3b or Class 4 laser (intended for removal only by service personnel) must have either an interlock or require a tool in the removal process. If an interlock is used and is defeatable, a warning label indicating this fact is required on the housing near the interlock. The design shall not allow replacement of a removed panel with the interlock in the defeated condition.

The FDA/CDRH Federal Laser Product Performance Standard requires warning labels on removable protective housing panels under all conditions.

*Protective Housing Interlock Requirements*

Interlocks, which cause beam termination or reduction of the beam to MPE levels, must be provided on all panels intended to be opened during operation and maintenance of all Class 3a, Class 3b, and Class 4 lasers. The interlocks are typically electrically connected
to a beam shutter. The removal or displacement of the panel closes the shutter and eliminates the possibility of hazardous exposures.

Under the requirements of the ANSI Z 136 Standard, for embedded Class3b and Class 4 lasers only, the interlocks are to be "fail-safe." This usually means that dual, redundant, electrical series-connected interlocks are associated with each removable panel.

Adjustments or procedures during service on the laser shall not cause the safety interlocks to become inoperative or the laser radiation outside a Class 1 laser protective housing to exceed the MPE limits, unless a temporary laser-controlled area is established. The interlocking requirements are summarized in Appendix L.

Remote Interlock Connector

A Class 3b or Class 4 laser or laser system should be provided with a remote interlock connector. The purpose of the remote interlock connector is to facilitate an electrical connection to an emergency master disconnect or entryway, floor or area interlock, as may be required for a Class 4 permanently attached beam stop attenuator.

Equipment Labels, (All Classes Except Class 1)

All lasers or laser systems (except Class 1) shall have appropriate warning labels with the laser sunburst logotype symbol and the appropriate cautionary statement. The label shall be affixed in a conspicuous place on both the housing and the control panel if these are separated by more than two meters.
An advisory label that indicates the relative hazard shall be placed on the protective housing when removal of non-interlocked protective housings allow access to laser radiation in excess or the applicable MPE.

The LSO shall effect the posting of advisory protective housing labels on long distance (>3 meters) beam conduits. Such labeling shall be placed on the outside of the conduit at appropriate intervals (approximately 3 meters), to provide a warning or the relative hazards of the laser radiation contained within the conduit.

*Area Warning Signs (All Classes Except Class 1)*

An area that contains a Class 2 laser or laser system should be posted with the appropriate caution sign. An area which contains a Class 3a laser or laser system should be posted with the appropriate caution or danger sign depending on the irradiance. An area which contains Class 3a lasers and laser systems that exceed the appropriate MPE for irradiance and all Class 3b or Class 4 laser or laser systems shall be posted with the appropriate danger sign.

*Laser Use without Protective Housing (All Classes)*

In some circumstances, such as during the manufacture of lasers and during research and development, operation of an unenclosed laser or laser system may become necessary. In such cases, the LSO shall determine the hazard and ensure that controls are instituted.
appropriate to the class of maximum accessible emission to ensure safe operation. Such controls may include but are not limited to:

1) Access restriction
2) Eye protection
3) Area controls
4) Barriers, shrouds, beam stops, etc.
5) Administrative and procedural controls
6) Education and training

Optical Fiber (Light Wave) Communication Systems

Under normal operation such systems are completely enclosed (Class 1) with the optical fiber and optical connectors forming the enclosure. During installation or servicing, or when an accidental break in the cable occurs, the system can no longer be considered enclosed. If engineering controls limit the accessible emission to levels below the applicable MPE (irradiance), no controls are necessary. If the accessible emission is above the MPE, the following requirements shall apply:

1) Only authorized trained personnel shall be permitted to perform service on light wave transmission systems if access to laser emission is required.
2) Only authorized trained personnel shall be permitted to use the laser test equipment (Optical Loss Test Set, Optical Time Domain Reflectometer, etc.) during installation and/or service.
3) All unauthorized personnel shall be excluded from the immediate area of access to laser radiation during service and installation when there is a possibility that the system may become energized. The immediate area shall be considered a temporary laser-controlled area.

4) Staring into the end of any broken, severed, or unterminated optical fiber or cable shall be avoided.

5) The end of any broken, severed, or unterminated optical fiber shall not be viewed with unfiltered optical instruments (microscopes, telescopes, etc.). An exception to this is the use of indirect image converters such as an infrared image converter or closed-circuit television system for verification that a fiber is not energized.

6) During a splicing operation (either installation or service), if it is required that the ends of the fiber be examined with an eye-loupe for a satisfactory cut, only an eye-loupe containing an appropriate filter shall be used. If a fusion splicer is used, the appropriate operating safety procedures shall be rigidly adhered to.

Service and Repair of Lasers

Any service or repair of a laser or laser system that alters its operating characteristics shall be reviewed by the LSO to determine if:

1) The service or repair is safe to conduct in a multiple laser facility where personnel could be present

2) New or modified controls are required and implemented

3) Reclassification is necessary
4.4. Protective Equipment and PPE

4.4.1. General

Enclosure of the laser equipment or beam path is the preferred method of control, since the enclosure will isolate or minimize the hazard.

When other control measures do not provide adequate means to prevent access to direct or reflected beams at levels above the MPE, it may be necessary to use personal protective equipment such as eye protection in the form of goggles or spectacles, barriers, windows, clothing and gloves, and other devices which have been specifically selected for suitable protection against laser radiation.

It should be noted that personal protective equipment may have serious limitations when used as the only control measure with higher-power Class 4 lasers or laser systems; the protective equipment may not adequately reduce or eliminate the hazard, and may be damaged by the incident laser radiation.

4.4.2. Protective Eyewear (Class 3b or Class 4)

Eye Protection (Class 3b or Class 4)

Eye protection devices which are specifically designed for protection against radiation from Class 3b lasers or laser systems should be administratively required and their use
enforced when engineering or other procedural and administrative controls are inadequate to eliminate potential exposure in excess of the applicable MPE.

Eye protection devices which are specifically designed for protection against radiation from Class 4 lasers or laser systems shall be administratively required and their use enforced when engineering or other procedural and administrative controls are inadequate to eliminate potential exposure in excess of the applicable MPE.

Laser protective eyewear is usually not required for Class 2 or Class 3a lasers or laser systems except in conditions where intentional long-term (>0.25 seconds) direct viewing is required.

Laser protective eyewear may include goggles, face shields, spectacles, or other prescription eyewear using special filter materials or reflective coatings (or a combination of both) to reduce the potential ocular exposure below the applicable MPE level.

Laser protective eyewear shall be specifically selected to withstand either direct or diffusely scattered beams. In this case, the protective filter shall exhibit a damage threshold for a specified exposure time, typically 10 seconds. The Eyewear shall be used in a manner so that the damage threshold is not exceeded in the "worst-case" exposure scenario. Important in the selection of laser protective eyewear is the factor of flammability.
UV Laser Protection

Particular care shall be taken when using UV lasers or laser systems. Thus, in addition to other laser controls which apply to all laser systems, the following requirements shall also apply.

Exposure to UV radiation shall be minimized by using beam shields and clothing which attenuate the radiation to levels below the MPE for the specific UV wavelengths.

Hazardous by-products

Special attention shall be given to the possibility of producing undesirable reactions in the presence of UV radiation.

Personal Protective Equipment (PPE) shall be used when working with the open beam Class 3b or Class 4 UV lasers. This shall include both the face mask and skin protection.

Eyewear for protection against other agents

Physical and chemical hazards to the eye can be reduced by the use of face shields, goggles, and similar protective devices.

Factors in Selecting Appropriate Eyewear

The following factors shall be considered in selecting the appropriate laser protective eyewear to be used.
1) Laser power and/or pulse energy
2) Wavelength(s) of laser outputs
3) Potential for multi-wavelength operation
4) Radiant exposure or irradiance levels for which protection (worst case) is required
5) Exposure time criteria
6) Maximum permissible exposure (MPE)
7) Optical density requirement of eyewear filters at laser output wavelength
8) Angular dependence of protection afforded
9) Visible light transmission requirement and assessment of the effect of the eyewear on the ability to perform tasks while wearing the eyewear.
10) Need for side-shield protection and maximum peripheral vision requirement
11) Need for prescription glasses
12) Comfort and fit
13) Degradation of filter media, such as photo-bleaching
14) Strength of materials (resistance to mechanical trauma and shock)
15) Capability of the front surface to produce a hazardous specular reflection
16) Requirements for antifogging design or coatings

Specification of Optical Density

Optical density is the most important factor necessary to specify the adequate protection for a given laser. Optical density is based upon the “worst case” laser beam exposure incident on the filter material to the maximum allowed exposure to the eye. The LSO is responsible for determining the optical density. The LSO may delegate the determination
of optical density to personnel trained in laser safety, optical engineering or physics that are familiar with optical density computations.

The attenuation of Optical Density, $D_\lambda$, of laser protective eyewear at a specific wavelength shall be specified. Many lasers radiate at more than one wavelength; thus eyewear designed to have an adequate $D_\lambda$ for a particular wavelength could have a completely inadequate $D\lambda$ at another wavelength radiated by the same laser. This problem may become particularly serious with lasers that are tunable over broad frequency bands.

If the Actual Eye Exposure is given by $H_0$, then the $D_\lambda$ required of protective eyewear to reduce this exposure to the MPE is given by:

$$D\lambda = \log_{10} \left( \frac{H_0}{\text{MPE}} \right)$$

where the units of $H_0$ are the same as those of the appropriate MPE. It should be noted that optical densities greater than three or four (depending on exposure time) could reduce eye exposures below the ocular MPE but leave the unprotected skin surrounding the eyewear exposed to values in excess of the MPE for skin exposure. The optical density of the protective material shall be determined from all anticipated viewing angles and at all wavelengths.
Optical Density Time Basis Criteria

The time of intended use of the laser or laser systems shall be used as the time factor upon which the MPE computation is based when computing the optical density of the filter material.

Visible Transmission

Adequate optical density, \( D_x \), at the laser wavelength of interest shall be weighed with the need for adequate visible transmission.

Identification of Eyewear

All laser protective eyewear shall be clearly labeled with the optical density and wavelength for which protection is afforded.

Cleaning and Inspection

Periodic cleaning and inspection shall be made of protective eyewear to ensure the maintenance of satisfactory condition. The frequency of the safety inspection should be once per year, or as determined by the LSO. This shall include:

1) Periodic cleaning of laser eyewear.
2) Inspection of the attenuation material for pitting, crazing, cracking, discoloration, etc.
3) Inspection of the frame for mechanical integrity
4) Inspection for light leaks and coating damage
5) Eyewear in suspicious condition should be tested for acceptability or discarded.

**Purchasing Information for Protective Eyewear**

Laser Supervisors shall provide laser protective eyewear for all laser users. When purchasing laser protective eyewear, the following information shall be identified:

1) Wavelength(s) and corresponding optical density for which protection is afforded

2) Pertinent data such as damage threshold for laser safety purposes

3) Manufacturers’ recommendations on shelf life, storage conditions, and use

**Facility Window Protection (Class 3b or Class 4)**

Facility windows that are located within the NHZ of a Class 3b or Class 4 laser or laser system shall be provided with the appropriate absorbing filter, blocking barrier, or screen which reduces any transmitted laser radiation to levels below the applicable MPE level.

Such laser windows shall be specifically selected to withstand direct and diffusely scattered beams. In this case, the window barrier shall exhibit a damage threshold for beam penetration for a specified exposure time commensurate with the total hazard evaluation for the facility and specific application.

Important in the selection of the window are the factors of flammability and decomposition products of the window material. It is essential that the window not support combustion or release toxic airborne contaminants following a laser exposure.
**Laser Protective Barriers and Curtains (Class 3b or Class 4)**

A blocking barrier, screen, or curtain which can block or filter the laser beam at the entryway should be used inside the controlled area to prevent the laser light from exiting the area at levels above the applicable MPE level. In some cases, where the barrier does not extend completely to the ceiling or to the floor, the LSO shall conduct an NHZ analysis to assure safety is afforded to all individuals outside the barrier protected area.

Such laser barriers shall be specifically selected to withstand direct and diffusely scattered beams. In this case, the barrier shall exhibit a damage threshold for beam penetration for a specified exposure time commensurate with the total hazard evaluation for the facility and specific application.

Important in the selection of the barrier are the factors of flammability and decomposition products of the barrier material. It is essential that the barrier not support combustion or release toxic fumes following a laser exposure.
4.5. Labels and Signage

4.5.1. General

All protective equipment shall be permanently labeled.

4.5.2. Labeling of Protective Equipment (Class 3b or Class 4)

Labeling of Laser Protective Eyewear

All laser protective eyewear shall be labeled with the optical density and wavelength(s) for which protection is afforded. Color coding or other distinctive identification of laser protective eyewear is also suggested when rapid eyewear identification is needed in multi-laser environments.

Labeling of Laser Protective Windows

All laser protective windows shall be labeled with the optical density and wavelength(s) for which protection is afforded. All laser protective windows should also be labeled with the threshold limit (TL) and exposure time for which the limit applies and the conditions under which protection is afforded.

Labeling of Collecting Optics Filters

All permanently mounted collecting optics housings containing laser protective filters shall be labeled with the optical density and wavelength(s) for which protection is afforded. All collecting optics filter housings should also be labeled with the threshold
limit (TL) and exposure time for which the limit applies and the conditions under which protection is afforded.

 Labeling of Laser Protective Barriers

All laser protective barriers shall be labeled with the barrier threshold limit (TL) and exposure time for which the limit applies and the beam exposure conditions under which protection is afforded.

 Skin Protection (Class 3b or Class 4)

In some laser applications, such as use of excimer lasers operating in the ultraviolet, the use of a skin cover shall be employed if chronic (repeated) exposures are anticipated at exposure levels at or near the applicable MPE limits for skin.

Skin protection can best be achieved through engineering controls. If the potential exists for damaging skin exposure, particularly for ultraviolet lasers, then skin covers and or “sun screen” creams are recommended. Most gloves will provide some protection against laser radiation. Tightly woven fabrics and opaque gloves provide the best protection. For Class 4 lasers, consideration shall be given for flame retardant materials.

For wavelengths greater than 1.4μm, “large-area” exposures can cause heat loading, causing skin dryness and with excessive exposure, may lead to heat stress.

Chronic exposure may have long term adverse effects.
Other Personal Protective Equipment

Respirators, additional local exhaust ventilation, fire extinguishers, and hearing protection may be required whenever engineering controls cannot provide protection from a harmful ancillary environment.

4.6. Laser Warning Signs

4.6.1. Design of Signs

Sign dimensions, letter size and color, etc., shall be in accordance with the American National Standard Specification for Accident Prevention Signs.

4.6.2. Symbols

Two similar laser symbol designs are accepted for laser signs and labels.

1) ANSI Z535 Design

The laser hazard symbol shall be a sunburst pattern consisting of two sets of radial spokes of different lengths and one long spoke, radiating from a common center.

2) IEC 60825-1 Design

The laser hazard symbol shall be composed of an equilateral triangle surrounding a sunburst pattern consisting of two sets of radial spokes of different lengths and one spoke, radiating from a common center.
4.6.3. Safety Alert Symbol

A safety alert symbol is a symbol which indicates a potential personal safety hazard. It is composed of an equilateral triangle surrounding an exclamation mark. The symbol is to be located to the left of the signal word on the “Danger” or “Caution” signs. It is not used on the “Notice” signs.

4.6.4. Signal Words

The following signal words are used with the ANSI Z535 design laser signs and labels:

1) Danger

The signal word “Danger” shall be used with all signs and labels associated with all Class 3a lasers and laser systems that exceed the appropriate MPE for irradiance and all Class 3b and Class 4 lasers and laser systems.

2) Caution

The signal word “Caution” shall be used with all signs and labels associated with Class 2 lasers and laser systems and all Class 3a lasers and laser systems that do not exceed the appropriate MPE for irradiance.

3) Notice

The signal word “Notice” shall be used on signs posted outside a temporary laser controlled area.
4.6.5. Pertinent Sign Information

Sign information and warnings shall conform to the following specifications:

The appropriate signal word (Danger, Caution, or Notice) shall be located in the upper panel.

Adequate space shall be available on all signs and labels to allow for the inclusion of pertinent information. Such information may be included during the printing of the sign or label or may be handwritten in a legible manner, and shall include the following:

At position 1 above the tail of the sunburst, special precautionary instructions or protective action that may be applicable. The following are examples that may be applicable.

i) Laser Protective Eyewear Required

ii) Invisible Laser Radiation

iii) Knock Before Entering

iv) Do Not Enter When Light is On

v) Restricted Area

At position 2 below the tail of the sunburst, the type of laser, or the emitted wavelength, pulse duration, and maximum output.

At position 3, the class of the laser or laser system.
Location of Signs

All signs shall be conspicuously displayed in locations where they will best serve to warn onlookers.

4.6.6. Sign Conforming Information

Equipment labels shall conform to the following specifications:

At position 1 above the tail of the sunburst, special precautionary instructions or protective actions required by the reader such as:

For Class 2 lasers and laser systems, “Laser Radiation, Do Not Stare into Beam.”

For Class 3a lasers and laser systems where the accessible irradiance does not exceed the appropriate MPE based upon a 0.25 s exposure for wavelengths between 0.4 and 0.7 μm, “Laser Radiation -- Do Not Stare into Beam or View Directly with Optical Instruments”.

For all other Class 3a lasers and laser systems, “Laser Radiation – Avoid Direct Eye Exposure”.

For all Class 3b lasers and laser systems, “Laser Radiation – Avoid Direct Exposure to Beam”.
For Class 4 lasers and laser systems, "Laser Radiation – Avoid Eye or Skin Exposure to Direct or Scattered Radiation".

At position 2 below the tail of the sunburst, type of laser, or the emitted wavelength, pulse duration, and maximum output.

At Position 3, the class of the laser or laser system.

Location of Equipment Labels

All equipment warning labels shall be conspicuously displayed in locations on the equipment where they best will serve to warn onlookers.

4.7. Laser Safety Inspections and Monitoring

4.7.1. General

Laser/laser system inspections shall be conducted periodically on all Class 3B and Class 4 Lasers by the Laser Supervisor under the supervision of the LSO. The LSO will randomly inspect Class 3B and Class 4 lasers and laser systems to ensure that lasers and laser systems are in compliance with Local, State, and Federal regulations.

Under supervision of the LSO, the LS shall perform routine monitoring and inspections of all lasers and laser systems and present any findings to the LSO for evaluation. This process will enable the LSO to be aware of any laser safety concerns that may be present.
4.7.2. General Monitoring

The LS shall ensure that laser operations are in accordance with RIT's Laser Safety Manual and approved SOP's and shall immediately report any violations to the LSO.

The LSO shall periodically visit laser/laser system sites to ensure that lasers are operated according to RIT’s Laser Safety Manual and approved SOP’s. See Appendix M: RIT’s Laser Safety Audit Form.

Formal Inspections shall include the following:

Random laser inspections shall be performed annually by the LSO.

Inspection results shall be presented to the RSC.

Violations shall be brought to the attention of the LS

A formal report shall be presented to the LS for corrective actions.

4.7.3. Violation Levels

Violations shall be classified as major or minor. All violations shall be presented to the LSO and RSC.

*Major Violations*

Major Violations shall include but are not limited to:

1) Unauthorized personnel in the laser area when the laser in use
2) Haphazard use of lasers which could cause injury to personnel in and outside the laser area

3) Operating the laser/laser system outside of the operating procedures as specified in the SOP

4) Improper use of PPE when the laser is in use

5) Unauthorized use of lasers or laser systems

Major violations shall result in immediate loss of laser privileges and shall remain so until all safety concerns are addressed.

**Minor Violations**

Minor Violations shall include but are not limited to:

1) Improper posting of signs in the laser use area
2) Improper labeling of lasers and the laser area
3) SOP’s are not available or are not in the general vicinity of the laser/laser system

The LS shall present minor violations to the registrant for corrective actions and shall inform the LSO of the violation and of any corrective actions that were performed.

Providing security for all RIT resources from unauthorized access, misuse, or removal is the responsibility of all faculty and staff. Providing security for lasers is particularly important. When lasers are involved, this obligation rests primarily with the Laser Supervisor; however, all laboratory personnel have a responsibility to take reasonable precautions against theft or misuse of materials, particularly those that could threaten the public such as lasers. Any extraordinary laboratory security measures should be commensurate with the potential risks and imposed in a manner that does not unreasonably hamper research.


To facilitate education and research, lasers need to be accessible to students, faculty, and staff at RIT that have a legitimate need to use the lasers. However, individuals that do not need access to the lasers should not be permitted access to the lasers. All laboratory personnel are required to comply with the following security procedures:

(1) Question the presence of unfamiliar individuals in laboratories and report all suspicious activity immediately to Campus Safety by calling 475-3333.
(2) Report all suspicious activity to the Laser Supervisor.
(3) The Laser Supervisor should report threatening activities to the Laser Safety Officer and should ensure that access to the laser is further limited to essential personnel only.

(4) After normal business hours, all laboratories must be locked when not in use.

(5) Laboratory building exterior doors are secured after normal business hours.

To minimize the likelihood of unauthorized access, all after-hours building users should:

(1) Avoid providing building access to unfamiliar individuals

(2) Secure doors behind them

(3) Immediately report any building security problem to Campus Safety at 475-3333.

Any activities, including research, involving the use of lasers without the knowledge and approval of the Laser Supervisor are strictly prohibited.

4.8.2. Theft

Each person who possesses a laser or is responsible for a laser in a laboratory shall report to RIT’s Laser Safety Officer and Laser Supervisor immediately upon the occurrence of any of the following:

(1) Any theft or loss of an intact laser.

(2) Any theft or loss of any laser component.
4.9. Medical Surveillance

4.9.1. General

Medical surveillance is not required for students using Class 1, Class 2, or Class 3a lasers or laser systems. The LSO shall determine which students should be under medical surveillance, including those students working directly with Class 3b or Class 4 lasers or laser systems. Only an ocular baseline examination at the beginning of study with Class 3b or Class 4 lasers shall be required. The LSO should maintain a record of all medical examinations, including specific test results, for all personnel included in the medical surveillance program.

The user of the laser/laser system is required to inform the LS of any medical conditions that could cause the user to be at risk for chronic exposure. Conditions could include dermatological abnormalities of the skin and photosensitivity of the skin.

If a user is suspected of having a laser related injury, the user will immediately seek medical attention for evaluation and treatment, if needed. The user must submit the records of the medical examination to the LSO who in turn is responsible for maintaining these records with confidentiality according to privacy laws. The LSO and LS will investigate the cause of the incident and recommend corrective actions.
4.9.2. Eye Exam

The LS must ensure that all laser personnel and incidental personnel obtain a baseline eye exam. The ANSI Z136.1-2000 protocol requires only a baseline visual acuity test for incidental personnel.

The ANSI Z136.1-2000 protocol for baseline eye examinations for laser personnel includes:

1) Visual acuity
2) Ocular history
3) Amsler Grid Test
4) Color vision

Frequency of Medical Examinations

Incidental personnel are those whose work makes it possible but unlikely that they will be exposed to laser energy sufficient to damage their eyes or skin, e.g., custodial, electrical, clerical, and supervisory personnel not working directly with laser devices. Laser personnel are those who routinely work in laser environments and are ordinarily fully protected by engineering controls, administrative procedures, or both. For both incidental and laser personnel, examinations shall be performed prior to participation in laser work. Following any suspected laser injury, the pertinent required examinations will be repeated, in addition to other examinations required by the attending physician. Periodic examinations are not required.
Admission of photosensitive individuals to Class 3b or Class 4 laser areas should be discouraged. The LSO shall maintain on file the names of all additional students who are permitted within the NHZ of any laser or laser system under the LSO’s authority.

**Incidental personnel**

Incidental personnel are persons working in areas where there is a potential for exposure from laser energy (Class 3b or Class 4) that is sufficient to damage their eyes or skin. Incidental personnel shall have an eye examination for visual acuity prior to the working in areas where exposure to Class 3b and Class 4 lasers is a threat.
Appendix A: Emergency Contacts and General Laser Information:

Laser users should call the Campus Safety emergency number in any emergency situation at

Campus Safety: 475-3333 or x333

The Laser Safety Officer should be contacted for non-emergency questions or to request additional laser information at

Kelly Henry: 475-6270

The Radiation Safety Officer should be contacted for emergency or non-emergency questions or to request additional radiation information at

Kelly Henry: 475-6270
Appendix B: Laser Classifications – Summary of Hazards

Laser Classifications – Summary of Hazards

Applies to

--- wavelength ranges ---

<table>
<thead>
<tr>
<th>Class</th>
<th>UV</th>
<th>VIS</th>
<th>NIR</th>
<th>IR</th>
<th>Direct ocular</th>
<th>Diffuse ocular</th>
<th>Fire</th>
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<tbody>
<tr>
<td>I</td>
<td>X</td>
<td>x</td>
<td>X</td>
<td>X</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>IA</td>
<td>--</td>
<td>X*</td>
<td>--</td>
<td>--</td>
<td>Only after</td>
<td>No</td>
<td>No</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1000 sec</td>
<td></td>
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</tr>
<tr>
<td>II</td>
<td>--</td>
<td>X</td>
<td>--</td>
<td>--</td>
<td>Only after</td>
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<td>0.25 sec</td>
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<tr>
<td>IIIA</td>
<td>X</td>
<td>X**</td>
<td>X</td>
<td>X</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
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<tr>
<td>IIIB</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Yes</td>
<td>Only when laser output is near Class IIIB limit of 0.5 Watt</td>
<td>No</td>
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<tr>
<td>IV</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Key:  X  = Indicates class applies in wavelength range.

  *  = Class IA applicable to lasers "not intended for viewing" ONLY.

  ** = CDRH Standard assigns Class IIIA to visible wavelengths ONLY. ANSI Z 136.1 assigns Class IIIA to all wavelength ranges.
### Appendix C: Typical Laser Classification – Continuous-Wave (CW) Lasers

<table>
<thead>
<tr>
<th>Wavelength (µm)</th>
<th>Laser Type</th>
<th>Wavelength (µm)</th>
<th>Class 1* (W)</th>
<th>Class 2 (W)</th>
<th>Class 3** (W)</th>
<th>Class 4 (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultraviolet 0.180 to 0.280</td>
<td>Neodymium: YAG (Quadruple)</td>
<td>0.266 only</td>
<td>≤9.6 x 10^9 for 8 hours</td>
<td>None</td>
<td>&gt; Class 1 but ≤ 0.5</td>
<td>&gt;0.5</td>
</tr>
<tr>
<td></td>
<td>Argon</td>
<td>0.275</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Ultraviolet 0.315 to 0.400</td>
<td>Helium-Cadmium</td>
<td>0.325 only</td>
<td>≤3.2 x 10^6</td>
<td>None</td>
<td>&gt; Class 1 but ≤ 0.5</td>
<td>&gt;0.5</td>
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<tr>
<td></td>
<td>Argon</td>
<td>0.351, 0.363</td>
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<tr>
<td></td>
<td>Krypton</td>
<td>0.3507, 0.3564</td>
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<td></td>
</tr>
<tr>
<td>Visible 0.400 to 0.700</td>
<td>Helium-Cadmium</td>
<td>0.4416 only</td>
<td>≤4 x 10^5</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Argon (Visible)</td>
<td>0.457</td>
<td>≤5 x 10^5</td>
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<td></td>
<td></td>
<td>0.476</td>
<td>≤1 x 10^4</td>
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<td></td>
<td></td>
<td>0.488</td>
<td>≤2 x 10^4</td>
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<td>0.514</td>
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<td></td>
<td>Krypton</td>
<td>0.530</td>
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<td></td>
<td></td>
<td>&gt; Class 2 but ≤ 0.5 &gt;0.5</td>
</tr>
<tr>
<td></td>
<td>Neodymium: YAG (Doubled)</td>
<td>0.532</td>
<td></td>
<td></td>
<td>&gt; Class 1 but ≤ 0.5 &gt;0.5</td>
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</tr>
<tr>
<td></td>
<td>Helium-Neon</td>
<td>0.543</td>
<td></td>
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<tr>
<td></td>
<td>Dye</td>
<td>0.400-0.550</td>
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<td></td>
<td>Helium-Selenium</td>
<td>0.460-0.550</td>
<td>≤0.4 x 10^4</td>
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<tr>
<td></td>
<td>Dye</td>
<td>0.550-0.700</td>
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<tr>
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<td>Helium-Neon</td>
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<tr>
<td></td>
<td>InGaAlP</td>
<td>0.670</td>
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<tr>
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<td>Ti:Sapphire</td>
<td>0.670</td>
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<td></td>
<td>Krypton</td>
<td>0.6471, 0.6764</td>
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<tr>
<td>Near 0.780</td>
<td>GaAlAs</td>
<td>0.780</td>
<td>≤5.6 x 10^4</td>
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<tr>
<td>Range</td>
<td>Material</td>
<td>Power (W)</td>
<td>AEL (W/cm²)</td>
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<td>-------------------</td>
<td>-----------</td>
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<tr>
<td>Infrared</td>
<td>GaAlAs</td>
<td>0.850</td>
<td>(\leq 7.7 \times 10^{-4})</td>
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<tr>
<td>0.700 to</td>
<td>GaAs</td>
<td>0.905</td>
<td>(\leq 9.9 \times 10^{-4})</td>
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<tr>
<td>1.400</td>
<td>Neodymium:YAG</td>
<td>1.064</td>
<td>(\leq 1.9 \times 10^{-3})</td>
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<td>Far Infrared</td>
<td>Helium-Neon</td>
<td>1.080</td>
<td>(\leq 1.9 \times 10^{-3})</td>
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<tr>
<td>1.400 to</td>
<td>InGaAsP</td>
<td>1.310</td>
<td>(\leq 1.5 \times 10^{-3})</td>
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<tr>
<td>10^3</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Holmium</td>
<td>2.100</td>
<td>(\leq 9.6 \times 10^{-3})</td>
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<td></td>
<td>Erbium</td>
<td>2.940</td>
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<td></td>
<td>Hydrogen Fluoride</td>
<td>2.600-3.000</td>
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<td>Helium-Neon</td>
<td>3.390 only</td>
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<td></td>
<td>Carbon Monoxide</td>
<td>5.000-5.500</td>
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<td>Carbon Dioxide</td>
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<td>Water Vapor</td>
<td>118</td>
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<tr>
<td></td>
<td>Hydrogen Cyanide</td>
<td>337</td>
<td>(\leq 9.5 \times 10^{-2})</td>
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</table>

* Assumes no mechanical or electrical design incorporated into laser system to prevent exposures from lasting to \(T_{acc} = 8\) hours (one workday); otherwise the Class 1 AEL could be larger than tabulated. Table A1 from ANSI Z 136.1 - 2000

**See 3.3.3.1 in ANSI Z 136.1 for definition of Class 3a**
## Appendix D: Typical Laser Classification – Single Pulse Lasers

<table>
<thead>
<tr>
<th>Wavelength (μm)</th>
<th>Laser Type</th>
<th>Wavelength (μm)</th>
<th>Pulse Duration (s)</th>
<th>Class 1* (J)</th>
<th>Class 3b (J)</th>
<th>Class 4 (J)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultraviolet</td>
<td>Excimer (ArF)</td>
<td>0.193</td>
<td>20 x 10⁻⁹</td>
<td>≤2.4 x 10⁻⁵</td>
<td>&gt; Class 1 but ≤0.125</td>
<td>&gt;0.125</td>
</tr>
<tr>
<td>0.180 to 0.400</td>
<td>Excimer (KrF)</td>
<td>0.248</td>
<td>20 x 10⁻⁹</td>
<td>≤2.4 x 10⁻⁵</td>
<td>&gt; Class 1 but ≤0.125</td>
<td>&gt;0.125</td>
</tr>
<tr>
<td></td>
<td>Neodymium: YAG Quadrupled (Q-sw)</td>
<td>0.266</td>
<td>20 x 10⁻⁹</td>
<td>≤2.4 x 10⁻⁵</td>
<td>&gt; Class 1 but ≤0.125</td>
<td>&gt;0.125</td>
</tr>
<tr>
<td></td>
<td>Excimer (XeCl)</td>
<td>0.308</td>
<td>20 x 10⁻⁹</td>
<td>≤5.3 x 10⁻⁵</td>
<td>&gt; Class 1 but ≤0.125</td>
<td>&gt;0.125</td>
</tr>
<tr>
<td></td>
<td>Nitrogen</td>
<td>0.337</td>
<td>20 x 10⁻⁹</td>
<td>≤5.3 x 10⁻⁵</td>
<td>&gt; Class 1 but ≤0.125</td>
<td>&gt;0.125</td>
</tr>
<tr>
<td></td>
<td>Excimer (XeF)</td>
<td>0.351</td>
<td>20 x 10⁻⁹</td>
<td>≤5.3 x 10⁻⁵</td>
<td>&gt; Class 1 but ≤0.125</td>
<td>&gt;0.125</td>
</tr>
<tr>
<td>Visible</td>
<td>Rhodamine 6G (Dye Laser)</td>
<td>0.450-0.650</td>
<td>1 x 10⁻⁶</td>
<td>&gt; Class 1 but ≤0.03</td>
<td>&gt;0.03</td>
<td></td>
</tr>
<tr>
<td>0.400 to 0.700</td>
<td>Copper Vapor</td>
<td>0.510, 0.578</td>
<td>2.5 x 10⁻⁹</td>
<td>≤1.9 x 10⁻⁷</td>
<td>&gt; Class 1 but ≤0.03</td>
<td>&gt;0.03</td>
</tr>
<tr>
<td></td>
<td>Neodymium: YAG Doubled (Q-sw)</td>
<td>0.532</td>
<td>20 x 10⁻⁹</td>
<td>10⁻⁷</td>
<td>&gt; Class 1 but ≤0.03</td>
<td>&gt;0.03</td>
</tr>
<tr>
<td></td>
<td>Ruby (Q-sw)</td>
<td>0.6943</td>
<td>20 x 10⁻⁹</td>
<td></td>
<td>&gt; Class 1 but ≤0.03</td>
<td>&gt;0.03</td>
</tr>
<tr>
<td></td>
<td>Ruby (Long Pulse)</td>
<td>0.6943</td>
<td>1 x 10⁻³</td>
<td>≤3.9 x 10⁶</td>
<td>&gt; Class 1 but ≤0.03</td>
<td>&gt;0.03</td>
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<tr>
<td>Near</td>
<td>Ti: Sapphire</td>
<td>0.700-</td>
<td>6 x 10⁻⁶</td>
<td>≤1.9 x 10⁻⁷</td>
<td>&gt; Class 1 but ≤0.03</td>
<td>&gt;0.03</td>
</tr>
<tr>
<td>Infrared</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.700 to 1.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alexandrite</td>
<td>0.720- 0.800</td>
<td>(1 \times 10^{-4})</td>
<td>(\leq 7.6 \times 10^{-7})</td>
<td>&gt; Class 1 but (\leq 0.033)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neodymium: YAG (Q-sw)</td>
<td>1.064</td>
<td>(20 \times 10^{-2})</td>
<td>(\leq 1.9 \times 10^{-6})</td>
<td>&gt; Class 1 but (\leq 0.125)</td>
<td></td>
<td></td>
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<tr>
<td>Far Infrared</td>
<td>1.4 to 10³</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Erbium: Glass (Q-sw)</td>
<td>1.540</td>
<td>(10 \times 10^{-9})</td>
<td>(\leq 7.9 \times 10^{-3})</td>
<td>&gt; Class 1 but (\leq 0.125)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Co: Magnesium-Fluoride</td>
<td>1.8-2.5</td>
<td>(80 \times 10^{-6})</td>
<td>(\leq 7.9 \times 10^{-4})</td>
<td>&gt; Class 1 but (\leq 0.125)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Holmium</td>
<td>2.100</td>
<td>(250 \times 10^{-6})</td>
<td>(\leq 7.9 \times 10^{-4})</td>
<td>&gt; Class 1 but (\leq 0.125)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrogen Fluoride</td>
<td>2.600-3.000</td>
<td>(0.4 \times 10^{-6})</td>
<td>(\leq 1.1 \times 10^{-4})</td>
<td>&gt; Class 1 but (\leq 0.125)</td>
<td></td>
<td></td>
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<tr>
<td>Erbium</td>
<td>2.940</td>
<td>(250 \times 10^{-6})</td>
<td>(\leq 5.6 \times 10^{-4})</td>
<td>&gt; Class 1 but (\leq 0.125)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon Dioxide (Q-sw)</td>
<td>10.6</td>
<td>(100 \times 10^{-9})</td>
<td>(\leq 7.9 \times 10^{-5})</td>
<td>&gt; Class 1 but (\leq 0.125)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon Dioxide</td>
<td>10.6</td>
<td>(1 \times 10^{-3})</td>
<td>(\leq 7.9 \times 10^{-4})</td>
<td>&gt; Class 1 but (\leq 0.125)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Assuming that both eye and skin may be exposed, i.e., 1.0 mm beam (area of limiting aperture = \(7.9 \times 10^{-3}\) cm²).

** Class 3b AEL varies from 0.033 to 0.480 J corresponding to wavelengths that vary between 0.720 and 0.800μm.

Table A1 from ANSI Z 136.1 – 2000
## Appendix E: Small Source MPE’s for Commonly Used Lasers

<table>
<thead>
<tr>
<th>Wavelength (μm)</th>
<th>MPE (W/cm²)</th>
<th>T*=0.25 s</th>
<th>T=10 s</th>
<th>T=600 s</th>
<th>T=3 x 10⁴ s</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂ 10.6</td>
<td>-</td>
<td>0.1</td>
<td>-</td>
<td>-</td>
<td>0.1</td>
</tr>
<tr>
<td>Nd:YAG (CW)²</td>
<td>1.33</td>
<td>-</td>
<td>5.1 x 10⁻³</td>
<td>-</td>
<td>1.6 x 10⁻³</td>
</tr>
<tr>
<td>Nd:YAG (CW)¹</td>
<td>1.064</td>
<td>-</td>
<td>5.1 x 10⁻³</td>
<td>-</td>
<td>1.6 x 10⁻³</td>
</tr>
<tr>
<td>Nd:YAG Q-switched³</td>
<td>1.064</td>
<td>-</td>
<td>17 x 10⁻³</td>
<td>-</td>
<td>2.3 x 10⁻⁶</td>
</tr>
<tr>
<td>GaAs (diode)</td>
<td>0.840</td>
<td>-</td>
<td>1.9 x 10⁻³</td>
<td>-</td>
<td>610 x 10⁻⁶</td>
</tr>
<tr>
<td>InGdAlP (diode)</td>
<td>0.670</td>
<td>2.5 x 10⁻³</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>HeNe</td>
<td>0.633</td>
<td>2.5 x 10⁻³</td>
<td>-</td>
<td>293 x 10⁻⁶</td>
<td>17.6 x 10⁻⁶</td>
</tr>
<tr>
<td>Krypton</td>
<td>0.647</td>
<td>2.5 x 10⁻³</td>
<td>-</td>
<td>364 x 10⁻⁶</td>
<td>28.5 x 10⁻⁶</td>
</tr>
<tr>
<td></td>
<td>0.568</td>
<td>2.5 x 10⁻³</td>
<td>-</td>
<td>31 x 10⁻⁶</td>
<td>18.6 x 10⁻⁶</td>
</tr>
<tr>
<td></td>
<td>0.530</td>
<td>2.5 x 10⁻³</td>
<td>-</td>
<td>16.7 x 10⁻⁶</td>
<td>1.0 x 10⁻⁶</td>
</tr>
<tr>
<td>Argon</td>
<td>0.514</td>
<td>2.5 x 10⁻³</td>
<td>-</td>
<td>16.7 x 10⁻⁶</td>
<td>1.0 x 10⁻⁶</td>
</tr>
<tr>
<td>XeFl³</td>
<td>0.351</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>33.3 x 10⁻⁶</td>
</tr>
<tr>
<td>XeCl³</td>
<td>0.308</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1.3 x 10⁻⁶</td>
</tr>
</tbody>
</table>

*T is the exposure duration

¹ Operating at less common 1.33 μm

² Pulsed operation at 11Hz, 12-ns pulsed, 20mJ/pulse

³ When repeated exposure levels are anticipated the MPE must be reduced by a factor of 2.5

ANSI Z136.5 – 2000
Appendix F: MPE for the Eye for Selected Single Pulse Lasers

<table>
<thead>
<tr>
<th>Laser Type</th>
<th>Wavelength (µm)</th>
<th>Pulse Duration (s)</th>
<th>MPE (J cm⁻²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excimer (ArF)</td>
<td>0.193</td>
<td>2 x 10⁻⁸</td>
<td>3 x 10⁻³</td>
</tr>
<tr>
<td>Excimer (XeCl)</td>
<td>0.308</td>
<td>2 x 10⁻⁸</td>
<td>6.7 x 10⁻³</td>
</tr>
<tr>
<td>Ruby (pulsed)</td>
<td>0.694</td>
<td>1 x 10⁻³</td>
<td>1 x 10⁻⁵</td>
</tr>
<tr>
<td>Nd:YAG (pulsed)</td>
<td>1.064</td>
<td>1 x 10⁻³</td>
<td>5 x 10⁻⁵</td>
</tr>
<tr>
<td>Nd:YAG (Q-Switched)</td>
<td>1.064</td>
<td>5-100 x 10⁻⁹</td>
<td>5 x 10⁻⁶</td>
</tr>
<tr>
<td>Carbon Dioxide (CO₂)</td>
<td>10.6</td>
<td>1 x 10⁻³</td>
<td>10 x 10⁻³</td>
</tr>
</tbody>
</table>
## Appendix G: Wavelengths of Most Common Lasers

<table>
<thead>
<tr>
<th>Laser type</th>
<th>Wavelength (μmeters)</th>
<th>Laser type</th>
<th>Wavelength (μmeters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argon fluoride (Excimer-UV)</td>
<td>0.193</td>
<td>Helium neon (yellow)</td>
<td>0.594</td>
</tr>
<tr>
<td>Krypton chloride (Excimer-UV)</td>
<td>0.222</td>
<td>Helium neon (orange)</td>
<td>0.610</td>
</tr>
<tr>
<td>Krypton fluoride (Excimer-UV)</td>
<td>0.248</td>
<td>Gold vapor (red)</td>
<td>0.627</td>
</tr>
<tr>
<td>Xenon chloride (Excimer-UV)</td>
<td>0.308</td>
<td>Helium neon (red)</td>
<td>0.633</td>
</tr>
<tr>
<td>Xenon fluoride (Excimer-UV)</td>
<td>0.351</td>
<td>Krypton (red)</td>
<td>0.647</td>
</tr>
<tr>
<td>Helium cadmium (UV)</td>
<td>0.325</td>
<td>Rohodamine 6G dye (tunable)</td>
<td>0.570-0.650</td>
</tr>
<tr>
<td>Nitrogen (UV)</td>
<td>0.337</td>
<td>Ruby (CrAlO₃) (red)</td>
<td>0.694</td>
</tr>
<tr>
<td>Helium cadmium (violet)</td>
<td>0.441</td>
<td>Gallium arsenide (diode-NIR)</td>
<td>0.840</td>
</tr>
<tr>
<td>Krypton (blue)</td>
<td>0.476</td>
<td>Nd:YAG (NIR)</td>
<td>1.064</td>
</tr>
<tr>
<td>Argon (blue)</td>
<td>0.488</td>
<td>Helium neon (NIR)</td>
<td>1.15</td>
</tr>
<tr>
<td>Copper vapor (green)</td>
<td>0.510</td>
<td>Erbium (NIR)</td>
<td>1.504</td>
</tr>
<tr>
<td>Argon (green)</td>
<td>0.514</td>
<td>Helium neon (NIR)</td>
<td>3.39</td>
</tr>
<tr>
<td>Krypton (green)</td>
<td>0.528</td>
<td>Hydrogen fluoride (NIR)</td>
<td>2.70</td>
</tr>
<tr>
<td>Frequency doubled</td>
<td>0.532</td>
<td>Carbon dioxide (FIR)</td>
<td>9.6</td>
</tr>
<tr>
<td>Nd YAG (green)</td>
<td></td>
<td>Carbon dioxide (FIR)</td>
<td>10.6</td>
</tr>
<tr>
<td>Helium neon (green)</td>
<td>0.543</td>
<td></td>
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</tr>
<tr>
<td>Krypton (yellow)</td>
<td>0.568</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Copper vapor (yellow)</td>
<td>0.570</td>
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</tbody>
</table>

**Key:**
- **UV** = ultraviolet (0.200-0.400 μm)
- **VIS** = visible (0.400-0.700 μm)
- **NIR** = near infrared (0.700-1.400 μm)
Appendix H: Optical Densities for Protective Eyewear for Various Laser Types

<table>
<thead>
<tr>
<th>Laser type and power</th>
<th>Wavelength (mm)</th>
<th>0.25 $</th>
<th>10 $</th>
<th>600 $</th>
<th>30,000 $</th>
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</thead>
<tbody>
<tr>
<td>XeCl 50 Watts</td>
<td>0.308</td>
<td>--</td>
<td>6.2</td>
<td>8.0</td>
<td>9.7</td>
</tr>
<tr>
<td>XeFl 50 Watts</td>
<td>0.351</td>
<td>--</td>
<td>4.8</td>
<td>6.6</td>
<td>8.3</td>
</tr>
<tr>
<td>Argon 1.0 Watts</td>
<td>0.514</td>
<td>3.0</td>
<td>3.4</td>
<td>5.2</td>
<td>6.4</td>
</tr>
<tr>
<td>Krypton 1.0 Watt</td>
<td>0.530</td>
<td>3.0</td>
<td>3.4</td>
<td>5.2</td>
<td>6.4</td>
</tr>
<tr>
<td>Krypton 1.0 Watt</td>
<td>0.568</td>
<td>3.0</td>
<td>3.4</td>
<td>4.9</td>
<td>6.1</td>
</tr>
<tr>
<td>HeNe 0.005 Watt</td>
<td>0.633</td>
<td>0.7</td>
<td>1.1</td>
<td>1.7</td>
<td>2.9</td>
</tr>
<tr>
<td>Krypton 1 Watt</td>
<td>0.647</td>
<td>3.0</td>
<td>3.4</td>
<td>3.9</td>
<td>5.0</td>
</tr>
<tr>
<td>GaAs 50 mW</td>
<td>0.840</td>
<td>--</td>
<td>1.8</td>
<td>2.3</td>
<td>3.7</td>
</tr>
<tr>
<td>Nd: YAG 100 Watt</td>
<td>1.064</td>
<td>--</td>
<td>4.7</td>
<td>5.2</td>
<td>5.2</td>
</tr>
<tr>
<td>Nd: YAG (Q-switch)</td>
<td>1.064</td>
<td>--</td>
<td>4.5</td>
<td>5.0</td>
<td>5.4</td>
</tr>
<tr>
<td>Nd: YAG$^c$ 50 Watts</td>
<td>1.33</td>
<td>--</td>
<td>4.4</td>
<td>4.9</td>
<td>4.9</td>
</tr>
<tr>
<td>CO$_2$ 1000 Watts</td>
<td>10.6</td>
<td>--</td>
<td>6.2</td>
<td>8.0</td>
<td>9.7</td>
</tr>
</tbody>
</table>
Appendix I: Laser Safety Program Organization

**Radiation Safety Committee**

<table>
<thead>
<tr>
<th>Name</th>
<th>Position and Affiliation</th>
<th>Office</th>
<th>Home</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blondell, Scott</td>
<td>Center for Microelectronics</td>
<td>5-2171</td>
<td>315-331-7424</td>
<td><a href="mailto:spb1699@rit.edu">spb1699@rit.edu</a></td>
</tr>
<tr>
<td>Clark, Kate</td>
<td>Grants, Contracts, Intellectual Property, CIMS – Slaughter Building</td>
<td>5-7984</td>
<td></td>
<td><a href="mailto:kacgcip@rit.edu">kacgcip@rit.edu</a></td>
</tr>
<tr>
<td>John Zink</td>
<td>Risk Management and Safety Services</td>
<td>5-6131</td>
<td></td>
<td><a href="mailto:jgzrmss@rit.edu">jgzrmss@rit.edu</a></td>
</tr>
<tr>
<td>Gupta, Vinnie</td>
<td>Mechanical Engineering</td>
<td>5-2158</td>
<td>248-2493</td>
<td><a href="mailto:skgeme@rit.edu">skgeme@rit.edu</a></td>
</tr>
<tr>
<td>Henry, Kelly (LSO, RSO)</td>
<td>Environmental, Health, and Safety, Campus Safety</td>
<td>5-6270</td>
<td></td>
<td><a href="mailto:kahecps@rit.edu">kahecps@rit.edu</a></td>
</tr>
<tr>
<td>Kahn, Bruce</td>
<td>School of Photographic Arts &amp; Sciences</td>
<td>5-7219</td>
<td>271-2118</td>
<td><a href="mailto:bekpph@rit.edu">bekpph@rit.edu</a></td>
</tr>
<tr>
<td>Wagner, Jerome</td>
<td>Department of Physics</td>
<td>5-5150</td>
<td>244-8262</td>
<td><a href="mailto:jxwsps@rit.edu">jxwsps@rit.edu</a></td>
</tr>
<tr>
<td>Waterstram-Rich, Kristen (Chair)</td>
<td>Department of Medical Sciences</td>
<td>5-5117</td>
<td>248-2745</td>
<td><a href="mailto:kmw4088@rit.edu">kmw4088@rit.edu</a></td>
</tr>
<tr>
<td>Laser Supervisor</td>
<td>Location BLDG/RM#</td>
<td>Type of Laser</td>
<td>Power of Laser</td>
<td>Classification of Laser</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>-------------------</td>
<td>---------------</td>
<td>----------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>Richard Hirsch/Gerald Takacs</td>
<td>08-A213</td>
<td>HeNe</td>
<td></td>
<td>Metrologics</td>
</tr>
<tr>
<td>Michael Kotlarchyk</td>
<td>08-3237</td>
<td>Alexandrite</td>
<td>10 JOULES</td>
<td>Class 3b</td>
</tr>
<tr>
<td>Thomas Gennett/William Vanderveer</td>
<td>08-3237</td>
<td>Argon Ion</td>
<td>UP TO 6 WATTS</td>
<td>Class 4 Visible</td>
</tr>
<tr>
<td>Thomas Gennett/William Vanderveer</td>
<td>09-2395</td>
<td>HeNe</td>
<td>12mW</td>
<td>Class 4 Visible</td>
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<tr>
<td>Aliogut</td>
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<td>HeNe</td>
<td>30mW</td>
<td>Class 3b</td>
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<tr>
<td>RJ Hefner</td>
<td>09-2236</td>
<td>Ometron VH300+</td>
<td>1MW</td>
<td>Class 3b enclosed</td>
</tr>
<tr>
<td>Hany Ghoneim</td>
<td>17-2710</td>
<td>Drytek Quad 482 HeNe</td>
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<td>Class 3b</td>
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<tr>
<td>Thomas Grimsley</td>
<td>17-2716</td>
<td>Drytek Quad 482</td>
<td>5mW</td>
<td>Class 4</td>
</tr>
<tr>
<td>Scott Blondell</td>
<td>17-2720</td>
<td>NRC Uniphase 1101 HeNe</td>
<td></td>
<td>Class 3a</td>
</tr>
<tr>
<td>Lynn Fuller</td>
<td>17-2720</td>
<td>Encor Surfscan HeNe</td>
<td></td>
<td>Class 3b</td>
</tr>
<tr>
<td>Thomas Grimsley</td>
<td>17-2720</td>
<td>Tencor Surfscan</td>
<td>2mW</td>
<td>Class 3b</td>
</tr>
<tr>
<td>Scott Blondell</td>
<td>17-2720</td>
<td>NRC Uniphase 1101 HeNe</td>
<td>4mW</td>
<td>Class 3b</td>
</tr>
<tr>
<td>Lynn Fuller</td>
<td>17-2730</td>
<td>GCA-6700 Stepper HeNe</td>
<td></td>
<td>Class 3b</td>
</tr>
<tr>
<td>P. Waldrop</td>
<td>17-2750</td>
<td>GCA-6700 Stepper HeNe</td>
<td></td>
<td>Class 2</td>
</tr>
<tr>
<td>P. Waldrop</td>
<td>17-2720</td>
<td>NRC Uniphase 1101 HeNe</td>
<td>4mW</td>
<td>Class 2</td>
</tr>
<tr>
<td>Lynn Fuller</td>
<td>17-2830</td>
<td>GCA 4800 Stepper HeNe</td>
<td>1mW</td>
<td>Class 3b</td>
</tr>
<tr>
<td>P. Waldrop</td>
<td>17-2830</td>
<td>GCA 4800 Stepper HeNe</td>
<td>1mW</td>
<td>Class 2</td>
</tr>
<tr>
<td>Scott Blondell</td>
<td>17-2830</td>
<td>Omnichrome 439X HeCad</td>
<td></td>
<td>Class 2</td>
</tr>
<tr>
<td>Bruce Smith</td>
<td>17-2830</td>
<td>NRC Uniphase 1101 HeNe</td>
<td></td>
<td>Class 3b</td>
</tr>
<tr>
<td>Lynn Fuller</td>
<td>17-2830</td>
<td>Cymer</td>
<td>PULSED 5mJ</td>
<td>Class 3b</td>
</tr>
<tr>
<td>Scott Blondell</td>
<td>17-2830</td>
<td>ELS 4600</td>
<td>PULSED 30mJ</td>
<td>Class 4</td>
</tr>
<tr>
<td>Laser Supervisor</td>
<td>Location BLDG/RM#</td>
<td>Type of Laser</td>
<td>Power of Laser</td>
<td>Classification of Laser</td>
</tr>
<tr>
<td>------------------</td>
<td>-------------------</td>
<td>---------------</td>
<td>----------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>Scott Blondell</td>
<td>17-2830</td>
<td>EX 700</td>
<td>PULSED 6J</td>
<td>Class 4</td>
</tr>
<tr>
<td>Scott Blondell</td>
<td>78-2430</td>
<td>Kodak Lasers (Donation of 70)</td>
<td>Class 4</td>
<td>70-1357</td>
</tr>
<tr>
<td>Richard Cliver</td>
<td>08-3226</td>
<td>HeNe</td>
<td>.5MW</td>
<td>Class 4</td>
</tr>
<tr>
<td>Stockroom</td>
<td>08-3226</td>
<td>HeNe</td>
<td>.5MW</td>
<td>Class 2</td>
</tr>
<tr>
<td>Stockroom</td>
<td>08-3226</td>
<td>HeNe</td>
<td>.5MW</td>
<td>Class 2</td>
</tr>
<tr>
<td>Stockroom</td>
<td>08-3226</td>
<td>HeNe</td>
<td>.5MW</td>
<td>Class 2</td>
</tr>
<tr>
<td>Stockroom</td>
<td>08-3226</td>
<td>HeNe</td>
<td>.5MW</td>
<td>Class 2</td>
</tr>
<tr>
<td>Stockroom</td>
<td>08-3226</td>
<td>HeNe</td>
<td>.5MW</td>
<td>Class 2</td>
</tr>
<tr>
<td>Stockroom</td>
<td>08-3226</td>
<td>HeNe</td>
<td>.5MW</td>
<td>Class 2</td>
</tr>
<tr>
<td>Stockroom</td>
<td>08-3226</td>
<td>HeNe</td>
<td>.5MW</td>
<td>Class 2</td>
</tr>
<tr>
<td>Stockroom</td>
<td>08-3226</td>
<td>HeNe</td>
<td>.5MW</td>
<td>Class 3b</td>
</tr>
</tbody>
</table>
Appendix K: Laser Registration Form

Instructions: All Class 3b and 4 lasers are required to be registered with RIT’s Laser Safety Officer. Complete this form for each laser to be registered and forward to Laser Safety Officer, Campus Safety.

**Contact Information**

Registrant  
Telephone  
E-mail  
Contact Name  
Contact Phone  
Contact E-mail  
Building  
Department  
Room #

**Laser Information**

Laser Manufacturer  
Model Number  
Serial Number  
Laser Type  
Classification (3b or 4)  
Optical wavelength (nm)  
Beam diameter (nm)  
Beam divergence (nm)

**Mode**

Continuous Wave  
Average power (Watts)

Pulsed  
Energy  
Joules per pulse  
Pulse repetition frequency (Hz)

Q-switched  
Pulse width  
Energy  
Joules per pulse

Purpose or Use: __________________________________________________________

Comments: ____________________________________________________________

Laser Supervisor’s Signature ___________________________ Date ___________
Appendix L: Control Measures for the Four Laser Classes

<table>
<thead>
<tr>
<th>Control Measures</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineering Controls</td>
<td>1</td>
</tr>
<tr>
<td>Protective Housing without protective housing</td>
<td>X</td>
</tr>
<tr>
<td>Interlocks on protective housing</td>
<td>◊</td>
</tr>
<tr>
<td>Service Access Panel</td>
<td>◊</td>
</tr>
<tr>
<td>Key Control</td>
<td>--</td>
</tr>
<tr>
<td>Viewing Portals</td>
<td>--</td>
</tr>
<tr>
<td>Collecting Optics</td>
<td>MPE</td>
</tr>
<tr>
<td>Totally Open Beam Path</td>
<td>--</td>
</tr>
<tr>
<td>Limited Open Beam Path</td>
<td>--</td>
</tr>
<tr>
<td>Enclosed Beam Path</td>
<td>None required if protective housing in place</td>
</tr>
<tr>
<td>Remote Interlock Connector</td>
<td>--</td>
</tr>
<tr>
<td>Beam Stop or Attenuator</td>
<td>--</td>
</tr>
<tr>
<td>Activation Warning Systems</td>
<td>--</td>
</tr>
<tr>
<td>Emission Delay</td>
<td>--</td>
</tr>
<tr>
<td>Temporary Laser Controlled Area</td>
<td>◊</td>
</tr>
<tr>
<td>Remote Firing and Monitoring</td>
<td>--</td>
</tr>
<tr>
<td>Labels</td>
<td>X</td>
</tr>
<tr>
<td>Area Posting</td>
<td>--</td>
</tr>
</tbody>
</table>
### Administrative and Procedural Controls

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>NHZ</td>
<td>NHZ</td>
<td>NHZ</td>
<td>NHZ</td>
<td>NHZ</td>
<td>NHZ</td>
<td>NHZ</td>
<td>NHZ</td>
<td>NHZ</td>
<td>NHZ</td>
<td>NHZ</td>
<td>NHZ</td>
<td>NHZ</td>
</tr>
</tbody>
</table>

**LEGEND**

- **X** = shall
- **●** = should
- **= no requirement**
- **NHZ** = NHZ analysis required
- **◊** = shall if enclosed Class 3b or 4
- **MPE** = shall if MPE is exceeded
Appendix M: RIT’s Laser Safety Audit Form

Building
Room
Laser Supervisor
Date
Audit Performed by

<table>
<thead>
<tr>
<th>Audit Areas</th>
<th>Yes</th>
<th>No</th>
<th>NA</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Administrative</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lasers are classified appropriately (2, 3a, 3b, 4a, 4b)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard operating procedures are available</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alignment procedures are available</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Viewing cards are used for alignment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laser users attended appropriate training</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lasers are included in inventory</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<p>| <strong>Labeling and Posting</strong>    |     |    |    |          |
| Certification label present |     |    |    |          |
| Class designation and appropriate warning label present |     |    |    |          |
| Radiation output information on label |     |    |    |          |
| Aperture label present |     |    |    |          |
| Appropriate warning/danger sign at entrance to laser area |     |    |    |          |
| Warning posted for invisible radiation |     |    |    |          |</p>
<table>
<thead>
<tr>
<th>Audit Areas</th>
<th>Yes</th>
<th>No</th>
<th>NA</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Control Measures</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protective housing present and in good</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>condition</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beam attenuator present</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laser table below eye level</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beam is enclosed if possible</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beam not directed toward doors or windows</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beams are terminated with fire-resistant beam stops</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surfaces minimize specular reflections</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Controls are located so that the operator is not exposed to beam hazards</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Personal Protective Equipment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eye protection is appropriate for wavelength</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eye protection has adequate OD</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Warning/indicator lights can be seen through protective filters</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class 3b and 4 Lasers</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interlocks on protective housing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Service access panel present</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Limited access to spectators</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nominal hazard zone determined</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operators do not wear watches or reflective jewelry while laser is operating</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Audit Areas</td>
<td>Yes</td>
<td>No</td>
<td>NA</td>
<td>Comments</td>
</tr>
<tr>
<td>---------------------------------------------------------------------------</td>
<td>-----</td>
<td>----</td>
<td>----</td>
<td>----------</td>
</tr>
<tr>
<td>Viewing portals present where MPE is exceeded</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class 4 Lasers</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Failsafe interlocks at entry to controlled area</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area restricted to authorized personnel</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laser may be fired remotely</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Curtains are fire-resistant</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area designed to allow rapid emergency egress</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pulsed – interlocks designed to prevent firing of the laser by dumping the stored energy into a dummy load</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CW – interlocks designed to turn off power supply or interrupt the beam by means of shutters</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Beam Hazards</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High voltage equipment appropriately grounded</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High voltage equipment located away from wet surfaces or water sources</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High voltage warning label in place</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compressed gases secured</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix N: Training Requirements

The Laser Safety Officer has the fundamental responsibility for the assurance of the safe use of lasers owned and/or operated by Rochester Institute of Technology. The Laser Safety Officer shall establish and maintain an adequate program for the control of laser hazards. Rochester Institute of Technology requires training for Class 3b and Class 4 lasers and laser systems to be provided by the Laser Safety Officer. Rochester Institute of Technology requires training for Class 2 and Class 3a lasers, and for laser systems containing embedded Class 4 lasers to be provided by either the Laser Safety Officer or the Laser Supervisor.

Training Program

It is the responsibility of the Laser Safety Officer to ensure all appropriate personnel are trained. The Laser Safety Officer may provide the training in house or contract out training to qualified training organizations.

General Laser Safety Training

A 2-hour general laser safety training course is required for all persons who use lasers. An annual refresher training session will be provided as needed. Hands on training shall be provided by the Laser Supervisor for all laser users in their area for the specific lasers and hazards they will encounter while working there. This training must be certified in writing by the laser supervisor and each laser user. Topics for general laser safety training and refresher training shall include:
• Laser Safety Programs and Policies
• State and Federal Regulations and Standards
• Laser Concepts and Types
• Laser Classification
• Laser Hazards
• Bio-effects
• Non-beam Hazards
• Control Measures
• Protective Eyewear Requirements
• Medical Surveillance
• Nominal Hazard Zone
• Maximum Permissible Exposure
• Optical Density
Appendix O: Laser Safety Quiz

Multiple Choice: Circle the correct answer

1. RIT requires which classes of lasers to be registered with the Laser Safety Officer?
   a) Class 1
   b) Class 2
   c) Class 3a
   d) Class 3b
   e) Class 4
   f) c, d, and e
   g) d and e
   h) All of the above
   i) None of the above

2. The level of laser radiation to which a person may be exposed without hazardous effect or adverse biological changes in the eye or skin is the:
   a) Maximum permissible exposure limit
   b) Nominal hazard zone
   c) Laser controlled area
   d) Aversion response
   e) Accessible emission limit
3. Visible Radiation is electromagnetic radiation is:
   a) Radiation which can be detected by the human eye
   b) Commonly used to describe wavelengths in the range between 400 nm and 700-780 nm.
   c) Radiation with wavelengths between soft X-rays and visible violet light
   d) Radiation which is often broken down into UV-A (315-400 nm), UV-B (280-315 nm), and UV-C (100-280 nm)
   e) a and b
   f) c and d
   g) a
   h) c

4. When setting up the laser system, the laser beam should be set at what height?
   a) 4 feet
   b) 6 feet
   c) waist level
   d) eye level
   e) not at eye level
   f) all of the above
   g) none of the above
5. If a laboratory door is posted with “Danger, visible and invisible radiation, avoid direct exposure to beam”, what class of laser is being used in the laboratory?
   a. Class 1
   b. Class 2
   c. Class 3a
   d. Class 3b
   e. Class 4

6. If a laboratory door is posted with “Danger, visible and invisible radiation, avoid eye or skin exposure to direct or scattered radiation”, what class of laser is being used in the laboratory?
   a. Class 1
   b. Class 2
   c. Class 3b
   d. Class 3a
   e. Class 4
7. For which class of lasers is laser protective eyewear required?

   a. Class 1
   b. Class 2
   c. Class 3a
   d. Class 3b
   e. Class 4
   f. All of the above
   g. None of the above
   h. Class 3a, 3b, and 4
   i. Class 3b and 4

8. Labels are not required on which class of lasers?

   a. Class 1
   b. Class 2
   c. Class 3a
   d. Class 3b
   e. Class 4
   f. All of the above
   g. None of the above
9. Skin protection is required on which class(s) of lasers?
   a. All Classes
   b. Class 3a, 3b, and 4
   c. Class 3b and 4
   d. Class 4
   e. None of the above
   f. All of the above

10. All laser protective eyewear shall be clearly labeled with the
    a. Optical density
    b. Wavelength
    c. MPE
    d. NHZ
    e. a and b
    f. a and c
True/False: Circle the correct answer

1. Movement of the eyelid or the head to avoid an exposure to a noxious stimulant, bright light is known as aversion response.
   True or False

2. Laser is an acronym standing for light amplification by stimulated emission.
   True or False

3. Under normal operating conditions, Class 1 lasers are not considered a hazard.
   True or False

4. Class 4 lasers do not require an energy source to produce a beam.
   True or False

5. Laser light is monochromatic, non-directional, and coherent.
   True or False

6. Only Class 4 laser systems require posting of warning signs.
   True or False
   True or False

8. Ionizing radiation is radiation that has enough energy to vibrate atoms in a molecule, but lacks enough energy to remove the electron from its orbit around the nucleus.
   True or False

9. The laser medium is the material that is used to emit the laser light.
   True or False

10. Laser users are not permitted to energize or work with or near a laser/laser system unless authorized to do so by the supervisor of that laser.
    True or False
Appendix P: Rochester Institute of Technology Laser Certification Form

Requirements for Use of Class 3b and Class 4 Laser/Laser Systems

Name: ____________________________ Department ____________________________

E-mail Address: ______________________ Lab Phone #: ______________________

Laser Supervisor: _______________________

_____ Baseline eye exam Date: ____________

_____ Read R.I.T Laser Safety Manual Date: ____________

_____ Provided with appropriate eye protection Date: ____________

_____ Provided with specific training on safely operating laser system(s).
   By: ____________________________ Date: ____________

I have read and understand R.I.T’s Laser Safety Manual. I have received additional instruction on laser specific procedures for safely working with lasers in my work area. I agree to observe these procedures during the course of my work at Rochester Institute of Technology.

Applicant: ____________________________ Date: ____________

   Signature

I hereby confirm that this individual has completed the requirements for working with lasers at Indiana University. I will provide adequate supervision and any additional training necessary to ensure and that all laser safety procedures are observed during the course of his/her work in my laboratory.

I hereby confirm that this individual has completed the requirements for working with lasers at Rochester Institute of Technology. Adequate supervision and training will be provided in order to ensure that all laser safety procedures are followed. I will provide adequate supervision and any additional training necessary to ensure and that all laser safety procedures are observed during the course of his/her work in my laboratory.

Laser Supervisor: ____________________________ Date: ____________

   Signature

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Appendix Q: Warning Signs

CAUTION

DANGER
LASER REPAIR NOTICE

NOTICE

LASER REPAIR IN PROGRESS
BOLD BLACK LETTERING

Do not Enter When Light is Flashing
EYE PROTECTION REQUIRED

WHITE
BLUE

RED SYMBOL
Class 2 and Class 3a Laser Signs

**CAUTION**

LASER RADIATION
DO NOT STARE INTO BEAM

CLASS 2 LASER

**CAUTION**

LASER RADIATION
DO NOT STARE INTO BEAM
OR VIEW DIRECTLY
WITH OPTICAL INSTRUMENTS

CLASS 3a LASER

**DANGER**

LASER RADIATION
AVOID DIRECT EYE
EXPOSURE

CLASS 3a LASER

Class 3b Laser Signs

**DANGER**

LASER RADIATION
AVOID DIRECT EYE
EXPOSURE

CLASS 3B LASER

**DANGER**

INVISIBLE LASER RADIATION
AVOID DIRECT EXPOSURE
TO BEAM

CLASS 3B LASER

**DANGER**

VISIBL E AND/or INVISIBLE
LASER RADIATION
AVOID DIRECT EXPOSURE
TO BEAM

CLASS 3B LASER

Class 4 Laser Signs

**DANGER**

LASER RADIATION
AVOID EYE OR SKIN EXPOSURE
TO DIRECT OR SCATTERED
RADIATION

CLASS 4 LASER

**DANGER**

INVISIBLE LASER RADIATION
AVOID EYE OR SKIN EXPOSURE
TO DIRECT OR SCATTERED
RADIATION

CLASS 4 LASER

**DANGER**

VISIBL E AND/or INVISIBLE
LASER RADIATION
AVOID EYE OR SKIN EXPOSURE
TO DIRECT OR SCATTERED
RADIATION

CLASS 4 LASER
Appendix R: Standard Operating Procedure - Template

1. **Laser Information**

<table>
<thead>
<tr>
<th>Type:</th>
<th>Wavelength(s):</th>
<th>Classification:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturer:</td>
<td>Model:</td>
<td>Serial #:</td>
</tr>
<tr>
<td>Location Building:</td>
<td>Room:</td>
<td>Regist #:</td>
</tr>
<tr>
<td>Beam Diameter:</td>
<td>Beam Divergence:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>( ) Pulsed:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Q-Switched:</td>
<td>Max. Energy per pulse:</td>
</tr>
<tr>
<td></td>
<td>Pulse Duration:</td>
<td>Repetition Rate:</td>
</tr>
<tr>
<td>( ) Continuous Wave:</td>
<td>Max. Power:</td>
<td></td>
</tr>
</tbody>
</table>

2. **Laser Safety Contacts**  

   **Emergencies:** *Campus Safety* - 475-3333 or x333

   Laser Supervisor (LS):                    Department:

   Campus Safety Laser Safety Officer (LSO): Kelly Henry - 475-6270

   Campus Phone: 475-3333 or x333

   *Notify the Laboratory LS and LSO of all laser-related injuries.*
3. **Laser Safety Program**

Reference the Rochester Institute of Technology Laser Safety Manual for the following:

- Training requirements.
- Class 3b and Class 4 laser registration and disposal/transfer requirements.
- Medical surveillance (eye examination).
- Personal Protective Equipment (PPE), including protective eyewear.
- Standard Operating Procedures (SOPs).
- Signage and labeling requirements.
- Non-radiation hazards.

4. **Laser Application Summary (Complete a short summary of intended laser use)**
### 5. Hazards Present

<table>
<thead>
<tr>
<th>Y/N</th>
<th>Hazard</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Open/accessible laser beam.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Laser operations at eye level (standing or sitting).</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ultraviolet radiation/blue light exposure.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Non-beam related reflective surfaces (e.g. computer monitors, etc.) in vicinity of laser/laser beam(s).</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stray beam(s)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Exposed high voltage power supplies.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Exposed capacitors.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Collecting optics (e.g. microscopes, telescopes, etc.)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fumes/vapors.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Plasma radiation.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Compressed gases.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hazardous chemicals.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hazardous waste.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fire/Combustible Materials.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Researcher conducted laser maintenance (routine adjustments etc. not to include servicing).</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Poor housekeeping.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Other:</td>
<td></td>
</tr>
</tbody>
</table>
6. Controls

<table>
<thead>
<tr>
<th>Applicability</th>
<th>Control</th>
<th>Deficiency</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y/N</td>
<td>Entryway controls established (Engineered or Administrative).</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Control Area designated and appropriately posted.</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Nominal Hazard Zone (NHZ) established.</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Laser master switch (key or computer code).</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Key removed from laser system when not in use.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Laser beam enclosure utilized.</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Laser beam enclosure interlocks operational.</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Laser housing cover interlocks operational.</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Appropriate beam attenuators utilized.</td>
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<tr>
<td></td>
<td>Laser secured to base.</td>
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</tr>
<tr>
<td></td>
<td>Laser associated equipment secured to base.</td>
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<tr>
<td></td>
<td>Protective barriers (e.g. curtains, partitions).</td>
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<tr>
<td></td>
<td>Alignment Procedure Established</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Emergency off/stop (i.e. panic button) identified.</td>
<td></td>
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<tr>
<td></td>
<td>Rapid egress and emergency access satisfactory.</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Personal Protective Equipment (PPE)</td>
<td></td>
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<tr>
<td></td>
<td>Non-beam hazards addressed satisfactorily.</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Training requirements completed for all lab personnel.</td>
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<td></td>
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</tbody>
</table>
7. **Eyewear Criteria:** (Discard damaged or unfit eyewear!)

<table>
<thead>
<tr>
<th>Eyewear Criteria</th>
<th>Y/N</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sufficient pairs available.</td>
<td></td>
<td></td>
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<tr>
<td>Eyewear specific to laser wavelength(s).</td>
<td></td>
<td></td>
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<tr>
<td>Optical Density (OD) appropriate for all ranges of laser energy/power operations.</td>
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<tr>
<td>Proper fit.</td>
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<tr>
<td>Free of damage and or excessive scratches.</td>
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</tbody>
</table>

**Laser Eyewear Use**

<table>
<thead>
<tr>
<th>For this laser</th>
<th>Wear this eyewear</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of Laser</td>
<td>Notes</td>
</tr>
<tr>
<td>Wavelength (nm)</td>
<td>Designation/Manufacturer</td>
</tr>
<tr>
<td>Notes</td>
<td>Wavelength attenuated (nm)</td>
</tr>
<tr>
<td></td>
<td>Optical Density (OD)</td>
</tr>
<tr>
<td></td>
<td>Notes</td>
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</tbody>
</table>
Operating Procedures

- Initial preparation of lab environment and laser for normal laser operation (e.g. key position, interlock activated, outside warning signal on, identification of personnel, operational log, etc.).

- Alignment procedure:

- Target area preparation:

- Operational procedure (power settings, Q-switched mode, pulse rate, other):

- Shutdown procedure:

- Special procedures (e.g. servicing, maintenance, safety tests, interlock bypass, etc.):

- Emergency shutdown procedure:

- Hazardous waste disposal procedures (if applicable):
## Laboratory Personnel Listing

<table>
<thead>
<tr>
<th>Laser Users:</th>
<th>Training completed</th>
<th>Laser Non-users:</th>
<th>Training completed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>( )</td>
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<tr>
<td>10.</td>
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<td>10.</td>
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</table>
# 0. Laser User SOP Review

I have read this Standard Operating Procedure, understand the contents, and will utilize this procedure each time I use this laser or laser system.

<table>
<thead>
<tr>
<th>Name (print)</th>
<th>Signature</th>
<th>Date</th>
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</thead>
<tbody>
<tr>
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</tbody>
</table>

- This SOP shall be:
  - Read and understood by **laser users** prior to their initial use of the listed laser.
  - Reviewed by all **laser users** following any modifications to the laser or laser system that affects operational parameters.
  - Reviewed annually by all **laser users**.

- This SOP must be readily accessible and available for reference by laser users.

- Modifications to this SOP must be reviewed and approved by both the LS and the LSO.
LSO REVIEW

( ) Approved in Full or ( ) Deficiencies Noted

Date:
Name:
Signature:

LS REVIEW

Date:
Name:
Signature:
Appendix S: Glossary of Laser Terms

Absorb  To transform radiant energy into a different form, with a resultant rise in temperature.

Absorption  Transformation of radiant energy to a different form of energy by the interaction of matter, depending on temperature and wavelength.

Accessible Emission Level  The magnitude of accessible laser (or collateral) radiation of a specific wavelength or emission duration at a particular point as measured by appropriate methods and devices. Also means radiation to which human access is possible in accordance with the definitions of the laser's hazard classification.

Accessible Emission Limit (AEL)  The maximum accessible emission level permitted within a particular class. In ANSI Z 136.1, AEL is determined as the product of accessible emission Maximum Permissible Exposure limit (MPE) and the area of the limiting aperture (7 mm for visible and near-infrared lasers).

Aperture  An opening through which radiation can pass.

Argon  A gas used as a laser medium. It emits blue-green light primarily at 448 and 515 nm.

Attenuation  The decrease in energy (or power) as a beam passes through an absorbing or scattering medium.

Aversion Response  Movement of the eyelid or the head to avoid an exposure to a noxious stimulant, bright light. It can occur within 0.25 seconds, and it includes the blink reflex time.

Beam  A collection of rays that may be parallel, convergent, or divergent.

Beam Diameter  The distance between diametrically opposed points in the cross section of a circular beam where the intensity is reduced by a factor of $e^{-1}$ (0.368) of the peak level (for safety standards). The value is normally chosen at $e^{-2}$ (0.135) of the peak level for manufacturing specifications.

Beam Divergence  Angle of beam spread measured in radians or milliradians (1 milliradian = 3.4 minutes of arc or approximately 1 mil). For small angles where the cord is approximately equal to the arc, the beam divergence can be closely approximated by the ratio of the cord length (beam diameter) divided by the distance (range) from the laser aperture.

Blink Reflex  See aversion response.
Brightness  The visual sensation of the luminous intensity of a light source. The brightness of a laser beam is most closely associated with the radio-metric concept of radiance.

Carbon Dioxide  Molecule used as a laser medium. Emits far energy at 10,600 nm (10.6 μm).

Closed Installation  Any location where lasers are used which will be closed to unprotected personnel during laser operation.

CO₂ Laser  A widely used laser in which the primary lasing medium is carbon dioxide gas. The output wavelength is 10.6 μm (10600 nm) in the far infrared spectrum. It can be operated in either CW or pulsed.

Coherence  A term describing light as waves which are in phase in both time and space. Monochromaticity and low divergence are two properties of coherent light.

Collimated Light  Light rays that are parallel. Collimated light is emitted by many lasers. Diverging light may be collimated by a lens or other device.

Collimation  Ability of the laser beam to not spread significantly (low divergence) with distance.

Continuous Mode  The duration of laser exposure is controlled by the user (by foot or hand switch).

Continuous Wave (CW)  Constant, steady-state delivery of laser power.

Controlled Area  Any locale where the activity of those within are subject to control and supervision for the purpose of laser radiation hazard protection.

Diffuse Reflection  Takes place when different parts of a beam incident on a surface are reflected over a wide range of angles in accordance with Lambert's Law. The intensity will fall off as the inverse of the square of the distance away from the surface and also obey a Cosine Law of reflection.

Divergence  The increase in the diameter of the laser beam with distance from the exit aperture. The value gives the full angle at the point where the laser radiant exposure or irradiance is e⁻¹ or e⁻² of the maximum value, depending upon which criteria is used.

Embedded Laser  A laser with an assigned class number higher than the inherent capability of the laser system in which it is incorporated, where the system's lower classification is appropriate to the engineering features limiting accessible emission.

Emission  Act of giving off radiant energy by an atom or molecule.
Enclosed Laser Device  Any laser or laser system located within an enclosure which does not permit hazardous optical radiation emission from the enclosure. The laser inside is termed an "embedded laser."

Energy (Q)  The capacity for doing work. Energy is commonly used to express the output from pulsed lasers and it is generally measured in Joules (J). The product of power (watts) and duration (seconds). One watt second = one Joule.

Excimer "Excited Dimer"  A gas mixture used as the active medium in a family of lasers emitting ultraviolet light.

Fail-safe Interlock  An interlock where the failure of a single mechanical or electrical component of the interlock will cause the system to go into, or remain in, a safe mode.

Gas Discharge Laser  A laser containing a gaseous lasing medium in a glass tube in which a constant flow of gas replenishes the molecules depleted by the electricity or chemicals used for excitation.

Gas Laser  A type of laser in which the laser action takes place in a gas medium.

Helium-Neon (HeNe) Laser  A laser in which the active medium is a mixture of helium and neon. Its wavelength is usually in the visible range. Used widely for alignment, recording, printing, and measuring.

Infrared Radiation (IR)  Invisible electromagnetic radiation with wavelengths which lie within the range of 0.70 to 1000 μm. These wavelengths are often broken up into regions: IR-A (0.7-1.4 μm), IR-B (1.4-3.0 μm) and IR-C (3.0-1000 μm).

Intrabeam Viewing  The viewing condition whereby the eye is exposed to all or part of a direct laser beam or a specular reflection.

Irradiance (E)  Radiant flux (radiant power) per unit area incident upon a given surface. Units: Watts per square centimeter. (Sometimes referred to as power density, although not exactly correct).

Laser  An acronym for light amplification by stimulated emission of radiation. A laser is a cavity with mirrors at the ends, filled with material such as crystal, glass, liquid, gas or dye. It produces an intense beam of light with the unique properties of coherency, collimation, and monochromaticity.

Laser Accessories  The hardware and options available for lasers, such as secondary gases, Brewster windows, Q-switches and electronic shutters.

Laser Controlled Area  See Controlled Area.

Laser Device  Either a laser or a laser system.
Laser Medium (Active Medium) Material used to emit the laser light and for which the laser is named.

Laser Rod A solid-state, rod-shaped lasing medium in which ion excitation is caused by a source of intense light, such as a flash lamp. Various materials are used for the rod, the earliest of which was synthetic ruby crystal.

Laser Safety Officer (LSO) One who has authority to monitor and enforce measures to control laser hazards and effect the knowledgeable evaluation and control of laser hazards.

Laser System An assembly of electrical, mechanical and optical components which includes a laser. Under the Federal Standard, a laser in combination with its power supply (energy source).

Lens A curved piece of optically transparent material which, depending on its shape, is used to either converge or diverge light.

Light The range of electromagnetic radiation frequencies detected by the eye, or the wavelength range from about 400 to 760 nm. The term is sometimes used loosely to include radiation beyond visible limits.

Limiting Aperture The maximum circular area over which radiance and radiant exposure can be averaged when determining safety hazards.

Maintenance Performance of those adjustments or procedures specified in user information provided by the manufacturer with the laser or laser system, which are to be performed by the user to ensure the intended performance of the product. It does not include operation or service as defined in this glossary.

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

Nd:Glass Laser A solid-state laser of neodymium:glass offering high power in short pulses. A Nd-doped glass rod used as a laser medium to produce 1064 nm light.

Nd:YAG Laser Neodymium:Yttrium Aluminum Garnet. A synthetic crystal used as a laser medium to produce 1064 nm light.

Neodymium (Nd) The rare earth element that is the active element in Nd:YAG laser and Nd:Glass lasers.

Nominal Hazard Zone (NHZ) The nominal hazard zone describes the space within which the level of the direct, reflected or scattered radiation during normal operation
exceeds the applicable MPE. Exposure levels beyond the boundary of the NHZ are below the appropriate MPE level.

Optical Cavity (Resonator) Space between the laser mirrors where lasing action occurs.

Optical Density A logarithmic expression for the attenuation produced by an attenuating medium, such as an eye protection filter.

Optical Fiber A filament of quartz or other optical material capable of transmitting light along its length by multiple internal reflection and emitting it at the end.

Optical Pumping The excitation of the lasing medium by the application of light rather than electrical discharge.

Optical Radiation Ultraviolet, visible, and infrared radiation (0.35-1.4 μm) that falls in the region of transmittance of the human eye.

Output Power The energy per second measured in watts emitted from the laser in the form of coherent light.

Power The rate of energy delivery expressed in watts (Joules per second). Thus: 1 Watt = 1 Joule × 1 §

Protective Housing A protective housing is a device designed to prevent access to radiant power or energy.

Pulse A discontinuous burst of laser, light or energy, as opposed to a continuous beam. A true pulse achieves higher peak powers than that attainable in a CW output.

Pulse Duration The "on" time of a pulsed laser, it may be measured in terms of milliseconds, microseconds, or nanoseconds as defined by half-peak-power points on the leading and trailing edges of the pulse.

Pulsed Laser Laser which delivers energy in the form of a single or train of pulses.

Pump To excite the lasing medium. See Optical Pumping or Pumping.

Pumped Medium Energized laser medium.

Pumping Addition of energy (thermal, electrical, or optical) into the atomic population of the laser medium, necessary to produce a state of population inversion.

Radiant Energy (Q) Energy in the form of electromagnetic waves usually expressed in units of Joules (watt-seconds).

Radiant Exposure (H) The total energy per unit area incident upon a given surface. It is
used to express exposure to pulsed laser radiation in units of J/cm².

Reflection  The return of radiant energy (incident light) by a surface, with no change in wavelength.

Refraction  The change of direction of propagation of any wave, such as an electromagnetic wave, when it passes from one medium to another in which the wave velocity is different. The bending of incident rays as they pass from one medium to another (e.g., air to glass).

Resonator  The mirrors (or reflectors) making up the laser cavity including the laser rod or tube. The mirrors reflect light back and forth to build up amplification.

Ruby  The first laser type; a crystal of sapphire (aluminum oxide) containing trace amounts of chromium oxide.

Scanning Laser  A laser having a time-varying direction, origin or pattern of propagation with respect to a stationary frame of reference.

Secured Enclosure  An enclosure to which casual access is impeded by an appropriate means (e.g., door secured by lock, magnetically or electrically operated latch, or by screws).

Semiconductor Laser  A type of laser which produces its output from semiconductor materials such as GaAs.

Service  Performance of adjustments, repair or procedures on a non-routine basis, required to return the equipment to its intended state.

Solid Angle  The ratio of the area on the surface of a sphere to the square of the radius of that sphere. It is expressed in steradians (sr).

Source  The term source means either laser or laser-illuminated reflecting surface, i.e., source of light.

Tunable Laser  A laser system that can be "tuned" to emit laser light over a continuous range of wavelengths or frequencies.

Tunable Dye Laser  A laser whose active medium is a liquid dye, pumped by another laser or flash lamps, to produce various colors of light. The color of light may be tuned by adjusting optical tuning elements and/or changing the dye used.

Ultraviolet (UV) Radiation  Electromagnetic radiation with wavelengths between soft X-rays and visible violet light, often broken down into UV-A (315-400 nm), UV-B (280-315 nm), and UV-C (100-280 nm).
Visible Radiation (light)  Electromagnetic radiation which can be detected by the human eye. It is commonly used to describe wavelengths in the range between 400 nm and 700-780 nm.

Wavelength  The length of the light wave, usually measured from crest to crest, which determines its color. Common units of measurement are the micrometer (micron), the nanometer, and (earlier) the Angstrom unit.

YAG  Yttrium Aluminum Garnet, a widely used solid-state crystal composed of yttrium and aluminum oxides and a small amount of the rare earth neodymium.
Appendix T: Bibliography


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United States Environmental Protection Agency. Understanding Radiation.


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