ÖSTLING TECHNOLOGIES

Laser Safety Manual

The Safe Use of Marking Lasers

Introduction

The word *laser* is an acronym for Light Amplification by Stimulated Emission of Radiation. In this document, the word laser will be limited to electromagnetic radiation-emitting devices using light amplification by stimulated emission of radiation at wavelengths from 180 nanometers to 1 millimeter. The electromagnetic spectrum includes energy ranging from gamma rays to electricity. *Figure 1* illustrates the total electromagnetic spectrum and wavelengths of the various regions.

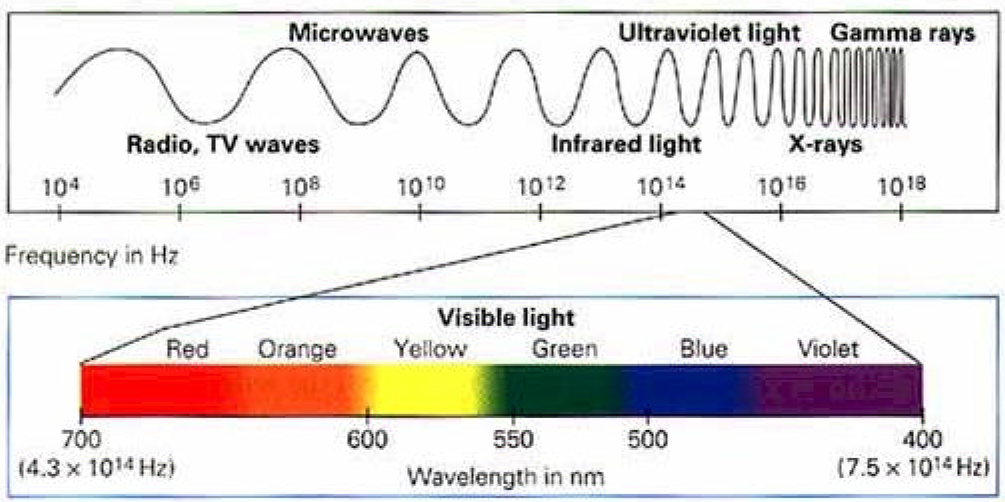


***Figure 1*. Electromagnetic Spectrum**

The primary wavelengths for lasers include the ultraviolet, visible and infrared regions of the spectrum. Ultraviolet radiation for lasers consists of wavelengths between 180 and 400 nanometers (nm). The visible region consists of radiation with wavelengths between 400 and 700 nm. This is the portion we call visible light. The infrared region of the spectrum consists of radiation with wavelengths between 700 nm and 1 mm.

The color or wavelength of light being emitted depends on the type of lasing material being used. For example, if a Neodymium:Yttrium Aluminum Garnet (Nd:YAG) crystal is used as the lasing material, light with a wavelength of 1064 nm will be emitted. Table 1 illustrates various types of material currently used for lasing and the wavelengths that are emitted by that type of laser. Note that certain materials and gases are capable of emitting more than one wavelength. The wavelength of the light emitted in this case is dependent on the optical configuration of the laser.

General

Lasers are safely used every day in many different applications and in many different environments around the world. Lasers do, however, present certain hazards, some even life threatening. A proper understanding of these hazards and the often-simple means of protecting against them is essential to ensure a safe environment for uses of this equipment.

Lasers used in the United States are subject to the controls of the Center for Devices and Radiological Health (C.D.R.H), a division of the FDA. The C.D.R.H. categorizes lasers in classes fro Class I to Class IV, according the risks they present. Most lasers used for marking applications are Class IV. Class IV lasers are defined as high power lasers which are hazardous to view (either specular or diffuse reflections), and are a potential fire and skin hazard.

While not strictly adopted by OSHA, the ANSI standard, Z136.1-2000, "Safe Use of Lasers", is considered an appropriate guideline for ensuring a safe environment where lasers are present. The ANSI standard requires that companies using Class IV lasers have a designated Laser Safety Officer (LSO). The LSO is one who has authority to monitor and enforce the control of lasers hazards. Typically the Industrial Hygiene department or the company Safety Specialist oversees the implementation of laser safety.

OSHA information concerning laser hazards can be assessed through the following link: http://www.osha-slc.gov/dts/osta/otm/otm_iii_6.html.

Common Laser Hazards

Other than the light that is emitted, lasers generate the same hazards as many other types of equipment. Common hazards are high voltage, compressed gases and intense radio frequency energy. The presence of these hazards depends upon the specific laser technology employed. For example, pulsed CO2 lasers can generate internal voltages in excess of 25,000 volts and often contain large capacitors capable of delivering over 200 Joules of energy. These lasers have interlocked enclosures, which should not be defeated. When opening the enclosures of these lasers, capacitive discharge procedures should be understood and strictly followed.

Pulsed lasers also typically use a flowing gas design, requiring connection to a cylinder if compressed gas. While most laser gases are very safe, pressurized cylinders can be hazardous and must be properly restrained during use and transportation.

Radio frequency energy can cause severe burns. Only trained personnel should service laser equipment employing RF generators (like sealed CO2 lasers). Connections carrying RF energy should never be touched during operation.

Often materials being marked give off fumes and gases. Sometimes these gases are noxious or even toxic. Fumes from laser marking should be controlled with an adequate vapor extraction system. When in doubt, a chemical analysis of the fumes is suggested to determine if any fume hazards exist.

Light Hazards

Laser systems are typically designed to prevent a beam from directly contacting a person. Risks, therefore, are more a result of unintentional reflected light. Reflected light falls into two categories, diffuse and specular. Diffuse reflections result when reflective surface irregularities scatter light in all directions. Diffuse reflections are typically much safer as the energy is split up into many directions.

Specular reflections are mirror-like reflections and can reflect close to 100% of the incident light. Because such a large percentage of the energy can be redirected, specular reflections are more hazardous. Note that as the diameter of the laser beam increases, the ability to cause damage decreases. Laser intensity is measured in power or energy over a measured area (W/cm2). While focused laser beams produce a very small spot size (and very intense energy) at the mark point, they are typically safer than unfocused beams because the laser beam size spreads out much more rapidly as the distance from the mark point increases.

While specular reflections are more hazardous, they are much less common. Most laser marking systems can be designed to eliminate specular reflective surfaces in the beam path.

Laser Radiation Effects on Skin

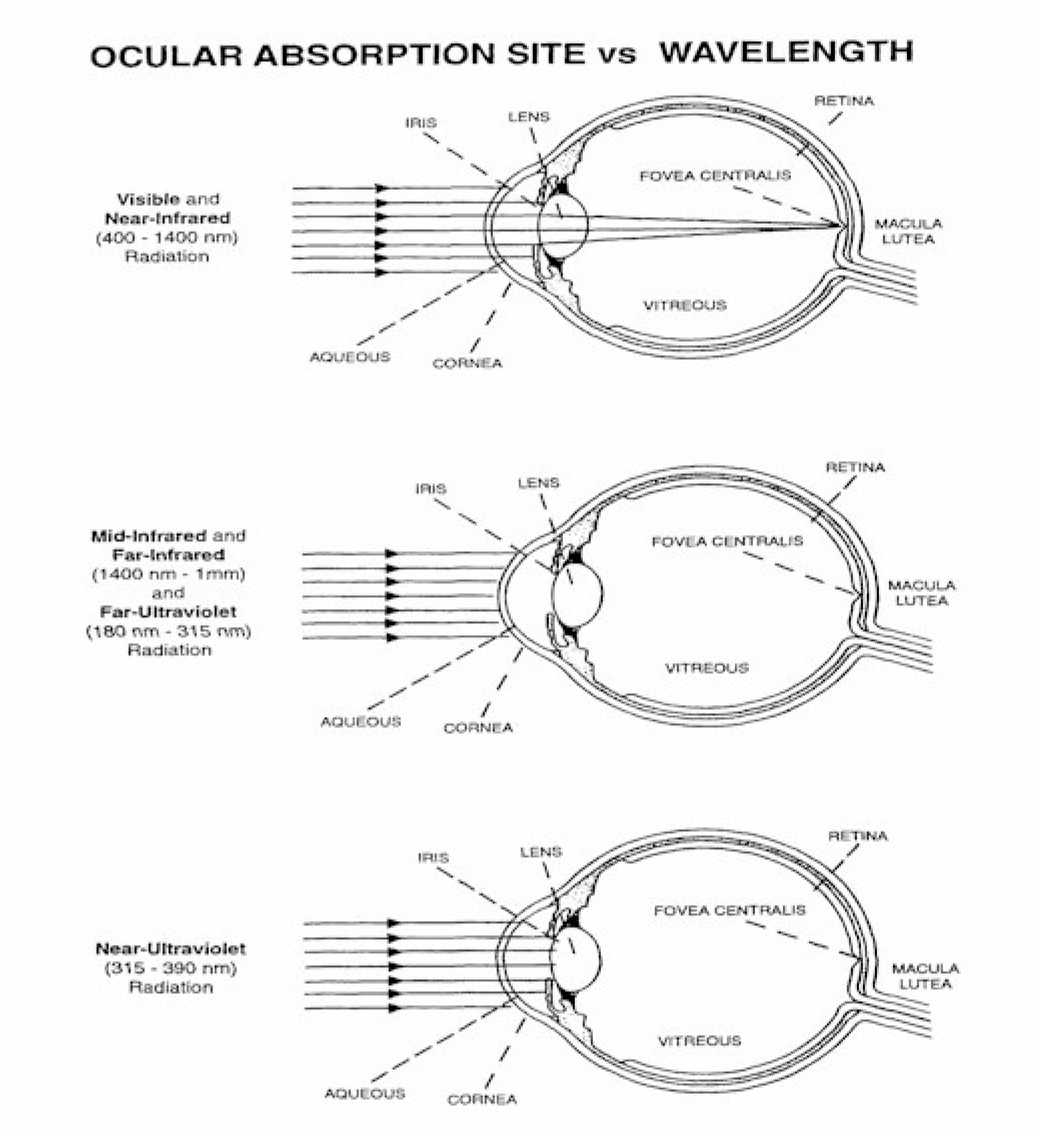
Skin effects are generally considered of secondary importance with lasers used for most marking applications. High power infrared lasers, like those used in cutting and welding applications, pose a larger skin effect hazard. Lasers emitting radiation in the visible and infrared regions produce effects that vary from mild, reddening to blisters and charring. These conditions are usually repairable or reversible. However, depigmentation, ulceration, and scarring of the skin, and damage to underlying organs may occur from extremely high powered lasers.

Laser Radiation Effects on the Eye

Visible Light and Infrared-A (400-1400 nm)

The marking laser most commonly used in this category is the Q-switched Nd:YAG laser, which operates at a typical wavelength of 1,064 nm. Eye exposure to this laser beam is more hazardous since at this wavelength the laser beam is transmitted through the eye and focused onto the retina. Exposure may initially go undetected because the beam is invisible and the retina lacks pain sensory nerves. Visual disorientation due to retinal damage may not be apparent to the operator until considerable thermal has occurred. Since the energy is concentrated by the eye's

lens, the strength of the laser beam that is required to damage the eye significantly less.



Maximum Permissible Exposure (MPE)

The MPE is defined in ANSI Z-136.1-1993 as "The level of laser radiation to which a person may be exposed without hazardous effect or adverse biological changes in the eye or skin. The MPE is not a distinct line between safe and hazardous exposures. Instead they are general maximum levels, to which various experts agree should be occupationally safe for repeated exposures. The biological effects of laser radiation are dependent on the wavelength and exposure duration. The goal of any control measures is to ensure that any laser radiation contacting a person is below the MPE.

Nominal Hazard Zone (NHZ)

In many marking applications, and most packaging applications, it is not practical to fully enclose the area where the laser beam is delivered onto the product. In these instances, it is necessary to define an area of potentially hazardous laser radiation. This area is called the Nominal Hazard Zone (NHZ). The NHZ is the space within which the level of direct, scattered or reflected laser radiation exceeds the MPE. The purpose of a NHZ is to define an area in which control measures are required. The Laser Safety Officer should determine the NHZ and the control measures to protect the laser worker from exposure to radiation above the MPE.

To quote the OSHA Technical Manual, Section III, Chapter 3: **"This (NHZ), is an important factor since, as the scope of laser uses has expanded, controlling lasers by total enclosure in a protective housing or interlocked room is limiting and in many instances an expensive overreaction to the real hazards."**

Carefully designed guarding can eliminate any real light hazards associated with laser radiation during equipment operation. This guarding can often be of very simple design. For example, the infrared emissions from a CO2 laser can be blocked by clear polycarbonate (lexan) sheet. Often a simple tunnel through which the product passes while being marked provides reliable, adequate protection, preventing unsafe exposure form the direct beam or any diffuse reflections.

Control Measures

Certain control measures need to be in place wherever there are lasers in use. The extent of the control measures is a function of the type of equipment installed, the nature of any shielding, and any maintenance procedures that may be undertaken. These control measures include:

Engineering Controls

Engineering controls include proper shield interlock designs (when required), and safe system operation controls, as in situations where the laser will be integrated into another control system.

Electrical Hazards

The use of lasers or laser systems can present an electric shock hazard. This may occur from contact with exposed utility power utilization, device control, and power supply conductors operating at potentials of 50 volts or more. These exposures can occur during laser set-up or installation, maintenance and service, where equipment protective covers are often removed to allow access to active components as required for those activities. The effect can range from a minor tingle to serious

personal injury or death. Protection against accidental contact with energized conductors by means of a barrier system is the primary methodology to prevent electrical shock.

Additional electrical safety requirements are imposed upon laser devices, systems and those who work with them by the federal Occupational Safety and Health Administration (OSHA), the National Electric Code and related state and local regulations. Individuals who repair or maintain lasers may require specialized electric safety-related work practices training.

Personal Protective Equipment

Protective Eyewear

In the case of virtually all laser marking installations, personal protective equipment is limited to the use of proper eyewear. Protective eyewear must be chosen with regard to the wavelength of the laser light and, where appropriate, the wavelength of any light emitted from the material surface during the marking process.

***Table 4.* Optical Densities for Protective Eyewear for Q-Switched Nd:Yag**

Laser Type/ Power	Wavelength (? m)	OD 0.25 seconds	OD 10 seconds	OD for 600 seconds	OD for 30,000 seconds
Nd:YAG (Q-switch)[b]	**1.064[a]**	**---**	**4.5**	**5.0**	**5.4**

Administrative and Procedural Controls

These controls largely involve access to the laser-controlled area, where required, controls put in place during abnormal conditions (such as equipment repair and

maintenance) and general safety rules (such as insisting that the equipment not be operated with shielding removed).

***Table 5*. Control Measures for the Four Laser Classes**

Control Measures	Classification					
Engineering Controls	**1**	**2a**	**2**	**3a**	**3b**	**4**
Protective Housing	X	X	X	X	X	X
without protective housing	Laser Safety Officer establishes alternative controls					
Interlocks on protective housing	?	?	?	?	X	X
Service Access Panel	?	?	?	?	X	X
Key Control	--	--	--	--	?	X
Viewing Portals	--	--	MPE	MPE	MPE	MPE
Collecting Optics	MPE	MPE	MPE	MPE	MPE	MPE
Totally Open Beam Path	--	--	--	--	X NHZ	X NHZ
Limited Open Beam Path	--	--	--	--	X NHZ	X NHZ
Enclosed Beam Path	None required if protective housing in place					
Remote Interlock Connector	--	--	--	--	?	X
Beam Stop or Attenuator	--	--	--	--	?	X
Activation Warning Systems	--	--	--	--	?	X
Emission Delay	--	--	--	--	--	X
Temporary Laser Controlled Area	? MPE	? MPE	? MPE	? MPE	--	--
Remote Firing and Monitoring	--	--	--	--	--	?
Labels	X	X	X	X	X	X
Area Posting	--	--	--	?	X	X

					NHZ	NHZ
Administrative and Procedural Controls						
Standard Operating Procedure	--	--	--	--	?	X
Output Emission Limitations	--	--	--	--	LSO Determines	
Education and Training	--	--	?	?	X	X
Spectator Controls	--	--	--	--	?	X
Service Personnel	? MPE	? MPE	? MPE	? MPE	X	X
Laser Fiber Optic Systems	MPE	MPE	MPE	MPE	X	X
Eye Protection	--	--	--	--	? MPE	X MPE
Protective Windows	--	--	--	--	X NHZ	X NHZ
Protective Barriers and Curtains	--	--	--	--	?	?
Skin Protection	--	--	--	--	X MPE	X MPE
LEGEND	X = shall ? = should -- = no requirement NHZ = NHZ analysis required ? = shall if enclosed Class 3b or 4 MPE = shall if MPE is exceeded					

Warning Signs and Labels

All Class 2, 3 and 4 laser equipment must be labeled indicating hazard classification, output power/energy, and lasing material or wavelength with words and symbols as indicated below:

Class 4 laser equipment: DANGER, Laser Radiation (or laser symbol) - Avoid Eye or Skin Exposure to Direct or Scattered Radiation

Labels and warning signs should be displayed conspicuously in areas where they would best serve to warn individuals of potential safety hazards. Normally, signs are posted at entryways to laser controlled areas and labels are affixed to the laser in a conspicuous location.

Conclusion

Laser marking systems can be operated safely and in compliance with national and regional safety requirements, often with very simple shielding and controls. The above material has been produced as guide for your company. It is the responsibility of each company to develop a laser safety program that complies with the national standard.