LASER SAFETY MANUAL

USER MANUAL

AMADA

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NOTICE

Please make sure that all personnel who operate, maintain, service or have access to your laser equipment read and understand this safety manual before they attempt to operate, maintain, or service your laser equipment.
It is very important that all personnel who have access to your laser equipment thoroughly understand the safe use of lasers.

CONTACT US

If there are any questions regarding laser safety after reading this Laser Safety Manual, please contact your company's Laser Safety Officer (LSO), or contact us at the address below:

Amada Weld Tech Inc.
1820 South Myrtle Avenue
Monrovia, CA 91016

Telephone: **(626) 303-5676**

FAX: **(626) 358-8049**

E-Mail: **info@amadaweldtech.com**

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CHAPTER 1
LASER SAFETY PRINCIPLES

Principal Hazards of Laser Systems

There are three principal hazards associated with laser operation: electrical shock, laser and collateral radiation, and toxic gases. Properly designed laser systems that are operated by careful, educated operators in an industrial environment constituted with safety in mind are no more hazardous than any other type of industrial machine, and are far safer than many.

Electrical Hazards

Of the three principal hazards associated with laser use, high voltage electricity, while not unique to lasers, is the most serious. This hazard may cause severe burns, nerve damage, and even instant death.

Causes of Death. Although the causes of death from electrical shock are not known with certainty, it is probably caused by asphyxiation or heart failure due to exhaustion and shock to the nervous system.

Respiration Inhibition. Respiration inhibition is dangerous because paralysis of the respiratory organs may last for a considerable period even after interruption of the current. Artificial resuscitation must be applied promptly to prevent suffocation.

Ventricular Fibrillation. Ventricular fibrillation is caused by moderately small currents. The ventricles go into asynchronous or fibrillary spasm in contrast to their normal synchronous contractions. It is believed that once ventricular fibrillation occurs, it is unlikely to stop spontaneously before death.

Tissue Destruction. Destruction of tissues due to high temperatures may cause complications leading to death. Patients who have been revived sometimes die suddenly without apparent cause. This may occur minutes, hours or even days after the accident. The phenomenon is thought to be due to aggravation of pre-existing conditions, or the result of hemorrhages affecting vital centers. It may also be due to shock or burns.

Biological Effects of Laser and Collateral Radiation

Amada Weld Tech Lasers do not emit collateral radiation due to their design.

General Overview. Laser radiation can cause irreversible damage to the skin and eyes. The principle cause of damage is thermal. Thermal damage is generally associated with lasers operating at exposure times greater than 10 microseconds in a wavelength from 0.315 to 10^3 micrometers.

Other damage mechanisms include photochemical reactions following exposures to either actinic ultraviolet radiation (0.200 to 0.315 micrometers) or short-wave visible radiation (0.4 to 0.55 micrometers), when exposures are greater than 10 seconds.

The principle damage mechanism for repetitively pulsed exposures is still questionable. It appears that the major mechanism is thermal, where the effect of the individual pulses is additive.

Skin and Internal Organs. Large skin surfaces make the skin susceptible to both acute and chronic exposures. Skin injury is less important than eye damage; however, the skin may be more often exposed to hazardous levels of radiation.

In the 0.3 to 1.0 micrometer range, almost 99% of the radiation penetrating the skin will be absorbed in the outer 4 mm of tissue.

Principle thermal effects depend on:

- Absorption and scattering coefficients
- Irradiance or radiant exposure
- Duration of the exposure
- Extent of the vascular flow
- Size of the area irradiated.

The ultraviolet spectrum is divided into three regions: UV-A, UV-B, and UV-C. UV-B exposure is the most injurious to the skin. Phototoxic and photosensitizing chemicals may exaggerate the effects of lasers operating in the visible and ultraviolet regions.

Biological effects on internal organs have not been observed except where the outer tissues have been surgically removed or massive laser exposure delivered to the tissue surface has caused surface ablation.

Thermal reaction of absorbed radiant energy in tissues is strongly dependent on both duration and area of the exposure. Refer to Table 1-1.

The Eye. The principle hazard associated with laser radiation is exposure to the eye. The particularly important regions of radiation hazard are in the visible and the near-infrared spectral regions. The parts of the eye are:

- Cornea
- Aqueous humor
- Lens

Table 1-1. Minimal Skin Reaction Levels

Laser Type	Radiant Exposure (J/cm^2)	Exposure Time (Seconds)
Ruby:		
Unpigmented Skin	11 – 20	2.5×10^{-3}
Pigmented Skin	2.2 – 6.9	2.5×10^{-3}
Q-Switched Ruby	0.25 – 0.24	75×10^{-9}
Argon	4.0 – 8.2	1.0
Carbon Dioxide	2.8	1.0
Neodymium Glass	2.5 – 5.7	75×10^{-9}
Q-Switched Neodymium Nd:YAG	46 – 78	1.0

X Iris
X Retina
X Macula fovea - sensitive to color and detail.

Retinal effects of visible optical radiation are influenced by the size of the retinal image and the time duration of the laser exposure. In general, the larger the pupil, the smaller the point spread and the greater the magnification factor at the retina as compared with the intensity at the cornea. The optical gain for a 7 mm diameter pupil is at least 1×10^5. It may be greater, depending on the magnitude of the experimental error in determining the data used in the estimates.

The most severe damage to the eye occurs at the fovea. Damage here will severely reduce visual function as regards to detail and resolution. Injury to the parafovea or the peripheral retina is less of a problem and may be undetectable from a functional point-of-view.

Effects on the Eye of Ultraviolet Wavelengths. Excessive ultraviolet wavelength exposure can produce photophobia accompanied by redness, tearing, discharge from the mucous membranes of the eyelid, corneal-surface cell-layer splitting and stromal haze. In the ultraviolet C and B regions, photokeratitis is the primary result of excessive acute (short-term) exposures. In the A region, cataracts may result from chronic high-level exposures. The hazards of C-region exposure may not be as great because this wavelength can be easily absorbed by protective clothing or in the outer dead layers of the epidermis.

Visible and Near-Infrared Wavelength Effects. Ocular hazards generally depend on which structure absorbs the most radiant energy per unit volume of tissue. Laser radiation can be focused to an extremely small spot size on the retina, causing excessive irradiance (W/cm^2) or radiant exposure (J/cm^2) incident on the retinal tissues even for modest corneal exposure levels.

In the visible portion of the spectrum, the cornea, lens and the ocular media are largely transparent. Only about 5% of the incident radiation is used for vision. The remainder is absorbed in the pigment granules of the retina. The absorbed energy is converted into heat, which can cause an irreversible retinal burn.

A retinal burn occurring in the macula is a very serious trauma. Destruction of this area degrades one's visual acuity to the point where the large “E” on the Snellen chart is no longer discernible; vision function is reduced to 10-200 or worse.

Blindness can be the result of a laser exposure that lasts only an infinitesimal fraction of a second. Similar damage in the periphery of the retina will often have minimal, if any functional significance. A macular burn would be the most probable result if the individual is viewing the beam directly. A peripheral burn may occur through an accidental exposure when the eye is not directly viewing the beam.

Effects of Far-Infrared Wavelengths on the Eye. A transition zone between the retinal effects and the effects on the front segments of the eye begins at the far end of the visible spectrum and extends into the infrared A region (0.780 to 1.4 micrometers).

Damage is observed to both the lens and the cornea in the infrared B range (1.4 to 3.0 micrometers).

The ocular media becomes opaque to radiation in the infrared C region (3.0 micrometers to 1 mm). The absorption by water (the major constituent of body cells) is high in these wavelengths.

Biological Damage Mechanisms. Until the late 1970's, it was not known that photo-chemical retinal injury mechanisms existed in addition to thermal injury. Laser safety thresholds and exposure limits for exposure durations from 10 microseconds up to 10 seconds seem to follow a constant power function, dependent on exposure duration. This implies only a thermal damage process. In this time domain, the retinal tissue is raised in temperature to a point where protein damage takes place.

Threshold studies support the present levels for allowable exposure limits for exposure durations of less than 10 seconds, provided that only a single long duration exposure is considered.

Repetitive short exposures (less than 10 microseconds) have a curious reduction in the threshold. The effects from pulses separated by several milliseconds appear to add, which would not be predicted on the basis of heat flow. The effects from two or three exposures of 10 micro-second pulses spread over several milliseconds are almost linearly additive. It is important to note that the Federal Laser Product Performance Standards do not include any corrections for multiple pulse exposures.

Photochemical Retinal Injury. The distinction between thermal and photochemical damage is that thermal damage is almost immediate in nature, while photochemical lesions take up to 48 hours to appear.

Dr. H. Zwick has done research that suggests that adverse and long term effects to retinal function result from large field diffuse reflection exposures to visible argon laser light. These effects occur at retinal irradiance levels in the magnitude of 10^{-7} W/cm^2, well below the present safety limits. The data also suggests that the effects are dependent upon the existence of the speckle pattern that is characteristic of diffused laser light. When the speckle was removed by vibrating diffusers in the laser beam projection optics, the effect was not noticed in some associated experiments.

A welding arc produced a geometrical retinal image of about 20 micrometers. The resulting lesion was approximately 100 micrometers. From the present studies of photochemical damage mechanisms, it is clear that this expanded lesion resulted from eye movement.

Summary of Basic Biological Effects. Table 1-2 is a summary of basic laser biological effects on the eye and skin.

Exposure Limits. There are several distinctions between the ANSI standard and the CDRH standard. One distinction is that the CDRH standard assumes only a simple linearly additive biological effect for exposure durations to visible light between 10 and 10^4 seconds. Another is that the ANSI standard for helium-neon lasers is about 17 times less restrictive than the CDRH standard.

The limits for CW (continuous wave) lasers in Class 1 are essentially identical for wavelengths between 400 and 550 nanometers.

> **NOTE:** In all matters of conflict, the CDRH regulations must prevail because they have the force of law.

Basic Effects of Laser and Collateral Radiation (continued)

Table 1-2. Basic Laser Biological Effects

Photobiological Spectral Domain	Eye	Skin
Ultraviolet C (200nm - 280nm)	Photokeratitis	Erythema (sunburn) Skin cancer Accelerated skin aging
Ultraviolet B (280nm - 315nm)	Photokeratitis	Increased pigmentation
Ultraviolet A (315nm - 400nm)	Photochemical cataract	Pigment darkening Photosensitive reactions Skin burn
Visible (400nm - 780nm)	Photochemical and thermal retinal injury	Photosensitive reactions Skin burn
Infrared A (780nm - 1400nm)	Cataract Retinal burn	Skin burn
Infrared B (1.4 µm - 3.0 µm)	Corneal burn Aqueous flare Cataract	Skin burn
Infrared C (3.0 µm - 1000 µm)	Corneal burn	Skin burn

Laser Classifications. The laser classification is a numbered system that is used to describe the capability of a laser or laser system to produce injury to personnel. The CDRH Class 1 laser is considered safe by all present measures of potential hazards. No individual, regardless of exposure conditions, would expect to be injured by a Class 1 laser (see Tables 1-3 and 1-4).

Class II lasers are limited to visible lasers where the exposure, considering the normal aversion response of the eye, would not be hazardous. The aversion response refers to the natural tendency of one exposed to a bright light to blink and turn away. It is considered by CDRH to be sufficient protection from excessive exposure to visible light lasers of low power. This would be a laser such as the helium-neon laser of 0.5mW.

Class IIa lasers are considered not for viewing. Class III lasers are medium powered laser systems that can do considerable damage to the eye.

Class IV lasers are unlimited power lasers. They can blind or burn the operator in a fraction of a second. These are considered the most dangerous lasers and should, in general, be avoided in the work place unless absolutely necessary for the material processing needs of the customer.

Table 1-3. Class 1 Accessible Emission Limits for Laser Radiation

Wave-length (Nano-meters)	Emission Duration (Seconds)	Class 1 - Accessible Emission Limits		
		Value	**Unit**	**Quantity**
> 180 but ≤ 400	≤ 3.0×10^4 > 3.0×10^4	$2.4 \times 10^5 k_1 k_2$* $8.0 \times 10^{10} k_1 k_2$*	Joules (J)* Watts (W)*	Radiant energy Radiant energy
> 400 but ≤ 1400	>1.0×10^9 to 2.0×10^5 >2.0×10^5 to 1.0×10^1 >1.0×10^1 to 1.0×10^4 >1.0×10^4	$2.0 \times 10^7 k_1 k_2$ $7.0 \times 10^4 k_1 k_2 t^{3/4}$ $3.9 \times 10^3 k_1 k_2$ $3.9 \times 10^7 k_1 k_2$	J J J W	Radiant energy Radiant energy Radiant energy Radiant power
	>1.0×10^9 to 1.0×10^1 >1.0×10^1 to 1.0×10^4 >1.0×10^4	$10k_1 k_2 t^{1/3}$ $20k_1 k_2$ $2.0 \times 10^3 k_1 k_2$	$Jcm^2 sr^1$ $Jcm^2 sr^1$ $Wcm^2 sr^1$	Integr radiance Integr radiance Radiant power
>1400 but ≤ 2500	>1.0×10^9 to 1.0×10^7 >1.0×10^7 to 1.0×10^1 >1.0×10^1	$7.9 \times 10^5 k_1 k_2$ $4.4 \times 10^3 k_1 k_2 t^{1/4}$ $7.9 \times 10^4 k_1 k_2$	J J W	Radiant energy Radiant energy Radiant power
>2500 but ≤ 1.0×10^6	>1.0×10^9 to 1.0×10^7 >1.0×10^7 to 1.0×10^1 >1.0×10^1	$1.0 \times 10^2 k_1 k_2$ $5.6 \times 10^1 k_1 k_2 t^{1/4}$ $1.0 \times 10^1 k_1 k_2 t$	Jcm^{-2} Jcm^{-2} Jcm^{-2}	Rad't exposure Rad't exposure Rad't exposure

NOTES *: Class 1 accessible limits for wavelengths equal to or greater than 180 nanometers but less than or equal to 400 nanometers shall not exceed the Class 1 accessible emission limits for the wavelengths greater than 1400 nanometers but less than or equal to 1.0×10^6 nanometers with a k_1 and k_2 of 1.0 for comparable sampling intervals. See Table 1-4 for solutions for k_1 and k_2.

Table 1-4. Selected Numerical Solutions for k_1 and k_2

Wavelength (Nanometers)	k_1*	k_2				
		t** = 100	t = 300	t = 1000	t = 3000	t = 10,000
180	1.0	All values = 1.0				
300	1.0					
302	1.0					
303	1.32					
304	2.09					
305	3.31					
306	5.25					
307	8.32					
308	13.2					
309	20.9					
310	33.1					
311	52.5					
312	83.2					
313	132.0					
314	209.0					
315	330.0					
400	330.0					
401	1.0					
500	1.0					
600	1.0					
700	1.0					
710	1.05	1.0	1.0	1.1	3.3	11.0
720	1.09	1.0	1.0	2.1	6.3	21.0
730	1.14	1.0	1.0	3.1	9.3	31.0
740	1.2	1.0	1.2	4.1	12.0	41.0
750	1.25	1.0	1.5	5.0	15.0	50.0
760	1.31	1.0	1.8	6.0	18.0	60.0
770	1.37	1.0	2.1	7.0	21.0	70.0

Wavelength (Nanometers)	k_1*	k_2				
		t** = 100	t = 300	t = 1000	t = 3000	t = 10,000
780	1.43	1.0	2.4	8.0	24.0	80.0
790	1.50	1.0	2.7	9.0	27.0	90.0
800	1.56	1.0	3.0	10.0	30.0	100.0
850	1.95	1.0	3.0	10.0	30.0	100.0
900	2.44	1.0	3.0	10.0	30.0	100.0
950	3.05	1.0	3.0	10.0	30.0	100.0
1000	3.82	1.0	3.0	10.0	30.0	100.0
1050	4.78	1.0	3.0	10.0	30.0	100.0
1060	5.00	1.0	3.0	10.0	30.0	100.0
1100	5.00	1.0	3.0	10.0	30.0	100.0
1400	5.00	1.0	3.0	10.0	30.0	100.0
1500	1.0	All values = 1.0				
1540	100.0*					
1600	1.0					
1.0×10^6	1.0					

NOTES: ***** The factor k_1 = 100.0 when t # 10^7 and k_1 = 1.0 when t > 10^7
****** The variable t is the magnitude of the sampling interval in units of seconds

Hazards of Toxic Gases and Vapors

Another problem that laser workers face is exposure to chemical vapors and industrial fumes. A summary of selected gas safety data that is of general applicability is shown in Table 1-5.

Table 1-5. Gas Safety Data

Gas	Flammable /% in Air	Pyrophoric/ % in Air- /Ignition °C	PPM Lethal in Few Min	PPM Lethal in Few Hrs	PPM Irritant Level	PPM Approx Odor Level	PPM 8 Hr TLV	Comments
AsH_3	Yes	?°C	250	6	--	1	0.05	Highly poisonous
PH_3	Yes	40 - 50°C	2,000	100	8	2	0.3	Highly poisonous
B_2H_2	0.8 - 88%	37 - 52°C	160?	?	1	3	0.1	Highly poisonous
NH_3	15 - 28%	650°C	30,000	--	25	5	50	Reacts strongly with chlorides
N_2O	Supports combustion	Non-auto	?	--	100	10	5	Anesthetic. Possible nerve damage
NO_2/ N_2O_4	Supports combustion	Non-auto	200?	--	60	10	5	--
CO_2	No	Non-auto	?	20000	--	--	5000	--
O_2	No	Non-auto	Non-lethal	--	--	--	--	Separate from reducers. Supports fierce combustion
SiH_4	Yes	0.5%SiH_4/H_2 4%SiH_4/N_2	Non-auto	Non-lethal	?	/	0.5	Forms fine silica dust and vigorous flame
SiH_4 Cl_2 $SiHl_2$ $SiCl_4$	No	--	?	8000	--	10	10	Decomposes to HCl and SiO_2
H_2	4080%	585°C	Asphyxiant	--	Non-irritant	Non-odorous	--	Store ≥ 2000 ft^3 building
N_2	No	--	Asphyxiant	--	Non-irritant	Non-odorous	--	--
HCL	No	--	1,300	10000	10	1	5	Noxious
HF	No	--	100 (?)	?	30	?	3	Noxious

Control of Hazards. There are a number of methods that are used to bring the risk of laser use into an acceptable limit. The Federal regulatory body responsible for administering the rules and regulations is the Occupational Safety and Health Administration (OSHA). The first method of risk control is the limitation of the amount of laser radiation to which an operator may legally be exposed. The second method is use of engineering controls to ensure that the set limits are not exceeded.

The third method is the use of personal protective devices such as safety eyewear and clothing. Finally, the use of administrative procedures within the company using lasers and employing laser operators is an important method of risk control.

CDRH Regulations. Lasers are classified by the level of laser radiation that the operator is exposed to during OPERATION. Radiation levels present during SERVICE or MAINTENANCE do not affect the classification at all. This means that a system which is Class 1, and completely safe during OPERATION, may necessarily expose service personnel to dangerous levels of laser radiation.

Limits of laser radiation are measured, depending on the wavelength and power, in:

- Radiant energy (Joules)
- Radiant power (Watts)
- Integrated radiance (J/ cm^{-2} sr^{-1})
- Radiance (W/cm^{-2} sr^{-1})
- Radiant exposure (J/cm^{-2})

Engineering Controls

Engineering controls are required to prevent human access to laser radiation in excess of the limits set by the class of the laser product.

Protective Housing. The protective housing is that portion of a laser product designed to prevent human access to laser or collateral radiation in excess of prescribed accessible emission limits.

Key-Switch Interlock. Each laser system classified as a Class IIIb or Class IV laser product shall incorporate a key-actuated master control. Amada Weld Tech has, as a matter of safe practice, incorporated a key switch into all laser products, regardless of class.

Beam Path Enclosure. The beam path enclosure encloses the beam path between parts of the laser system.

Beam Attenuator. Each laser system classified as a Class II, Class III, or Class IV laser product shall be provided with one or more permanently attached means capable of preventing access to all laser radiation in excess of Class 1 limits. All Amada Weld Tech lasers incorporate a safety shutter (beam path attenuator) in the laser cavity.

Visual or Audible Warning Systems. Laser products that incorporate safety interlocks designed to allow safety interlock defeat shall incorporate a means of visual or aural indication of interlock defeat. All Amada Weld Tech lasers have at least one LASER ON light mounted in a highly visible location. This light gives indication that the laser is on, or could come on.

Viewing Optics, Windows and Remote Viewing Systems. All viewing optics, view ports, and display screens incorporated into the laser product, regardless of class, must limit the levels of laser and collateral radiation accessible to the human eye to less than the accessible emission limits of Class 1.

Interlock Requirements. Each laser product, regardless of class, shall be provided with at least one safety interlock for each portion of the protective housing which is designed to be removed or displaced during operation or maintenance. All Amada Weld Tech Laser systems are fully interlocked.

Laser Controlled Areas. When the entire beam path of a Class IIIb or Class IV laser is not sufficiently enclosed and/or baffled, a laser controlled area should be established. Control may include the connection of the access to the area to the remote control connector (RCC) such that the laser is shut down when anyone enters the area. All Amada Weld Tech lasers are provided with an RCC, regardless of class.

Eye Protection. This is the use of eye wear of sufficient optical density to attenuate a beam of the appropriate wavelength for the laser system being used. Eyewear is specified in terms of the logarithmic units of Optical Density (OD). This value is calculated as $OD = \log_{10} (H_o/MPE)$ where H_o is the worst case exposure for the system, and MPE is the Maximum Permissible Exposure.

As an example of the calculation, take the 15J per millisecond output for the laser mill. Here, the ANSI standard has an MPE of 5 micro-Joules for a 1-millisecond exposure duration. Hence, using a 7 mm limiting aperture (diameter of the pupil), the $H_o = 15\ J / 0.385\ cm^2$. This implies:

$$OD = \log_{10} (38.96 / 5 \times 10^{-6}) = 6.9$$

> **WARNING:** Safety glasses or goggles rated at a minimum optical density of 6.0 at 1.064 nanometers would attenuate the beam to safe levels but do not rely on safety eyewear alone for protection against radiation exposure.

Safety Practices and Techniques. There are three important techniques for laser safety in the work place. The first important technique has to be the design of safe machines. This includes the installation and maintenance of engineering controls on the laser system. Next are the administration and procedures developed by OSHA, the State, and the company using the laser to promote a safe environment. This includes, but is not limited to, the hiring of the Laser Safety Officer (LSO). The responsibility of the LSO is to be aware of laser safety and the work place conditions, to promote safe practices, and provide laser safety training. The third important technique is the use of personal protective equipment. This includes appropriate eyewear and clothing for the operator of the laser system.

Laser Safety Officer: There are a number of good training programs in the industry to train personnel for the responsibilities of the LSO. These include:

- Administration of safety controls and regulations
- Training and education of laser and incidental personnel

Medical Surveillance and Examination Programs: These programs serve several purposes, including biological monitoring of occupational laser exposure, determination of adverse biological effects resulting from laser exposure, and the analysis of medical-legal issues. Medical-legal issues protect the employer from false compensation claims. As industrial experience with lasers has increased, it has become apparent that, with proper controls and education of laser workers, the need for periodic detailed medical surveillance has been reduced in scope.

Rather than subjecting laser workers to needless periodic examinations it has been determined that, in addition to an initial eye examination, the only eye exam of merit is the examination done immediately following a suspected over exposure to laser radiation along with the follow-up exams. Such a course of action is cost-effective and serves as a basis for establishing potential compensation claims.

> **NOTE:** All personnel who will be working on, or in the vicinity of, an Nd:YAG laser must have an initial eye examination on commencing their work *before* their first exposure to Nd:YAG laser radiation.

Several types of tests are performed in ocular examinations for laser workers. These include the fundus examination, visual acuity and visual field tests, and dark adaptation studies. However, the most important test is the visual acuity test. The presence of a visible laser retinal lesion does not necessarily mean functional impairment has occurred. If, however, there has been a significant effect on visual function following a laser exposure, it is likely to suspect the damage was done by the laser. In such a case, an eye examination by a qualified eye health practitioner is clearly required.

CHAPTER 2
PREPARING A LASER OPERATION STANDARD OPERATING PROCEDURE

These guidelines are intended to assist supervisors and management personnel who are responsible for the preparation of Standard Operating Procedures (SOPs) that detail specific requirements and procedures for operation of all lasers. These requirements and procedures are based on those specified by OSHA, the State and company regulations. It is intended that these requirements and procedures apply to operation of Class IIIb and Class IV lasers only.

Segments of the SOP

Introduction.

a. Location of the laser (site, building, room)

b. Description of the laser (beam characteristics, divergence, aperture diameter, and maximum output)

c. Purpose/applicability of beam

d. ANSI z136.1 Classification

e. Other (if applicable, include proposed use at the site, arrival data, pulse length, and repetition rate)

Hazards.

a. Identification of the hazards (beam, electrical, chemical)

b. Analysis of hazards (include target area, absorbing media)

Controls.

a. Access controls (door interlocks, signs, signals). See the *Laser Safety Signs and Labels Summary* later in this chapter.

b. Beam controls (key-lock, enclosures, shutters, stops)

c. Electrical controls (light on power supply, HV signs)

d. Eye protection (eye examination, type of eyewear, optical density for beam)

e. Other

Operating Procedures.

a. Initial preparation of laboratory environment (key position, warning lights on, interlock activated, identification of personnel)

b. Personnel protection (eyewear, isolation, barriers)

c. Target preparations

d. Countdown procedures

e. Shut down procedures

Emergency Procedures.

a. List potential emergencies and corresponding procedures

b. Describe specific rescue or evacuation procedures

Training.

a. Indoctrination of operating personnel

b. Training of on-site laser safety officer

Responsibilities.

a. Supervisory (include emergency contact)

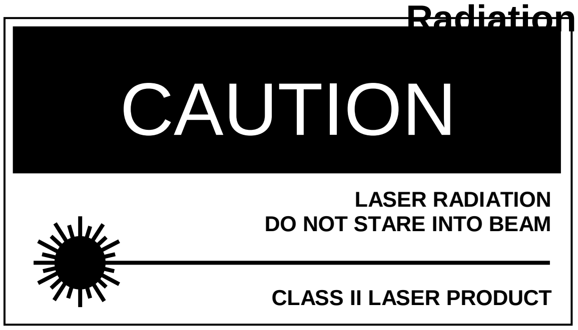
b. Support personnel

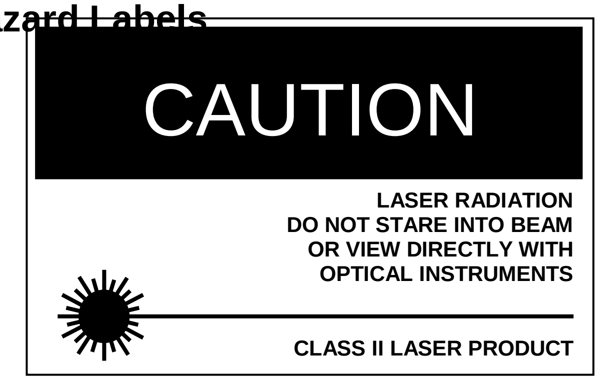
Definitions of Selected Medical Terms

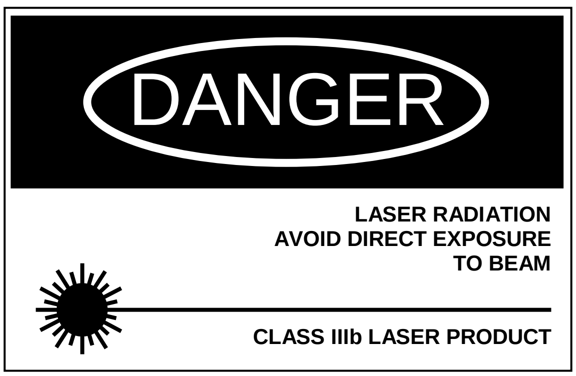
Ablation	Surgical excision or amputation of any part of the body.
Denaturation	To so modify a native protein, especially by heat, acid, alkali, or ultraviolet radiation, that some of the original properties (such as solubility and specific activity) are no longer present or present in the same degree owing to a change in molecular structure.
Erythema	A redness of the skin, as caused by chemical poisoning or sunburn.
Photo keratitis	Inflammation of the cornea of the eye characterized by burning or smarting, blurring of vision, and sensitivity to light.
Scotoma	An area of pathologically diminished vision within the visual field.

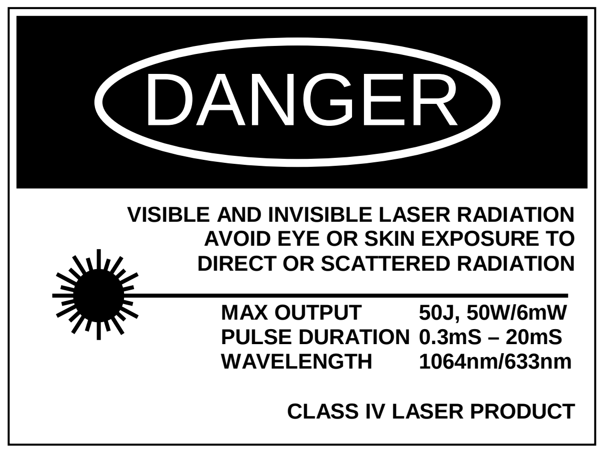
Laser Safety Signs and Labels Summary

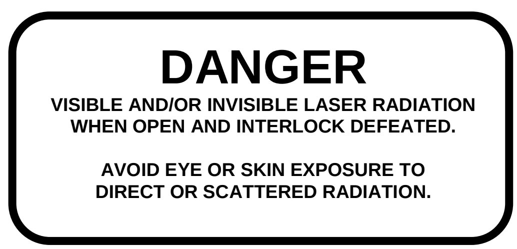
Radiation Hazard Labels











Laser Safety Signs and Labels Summary (continued)

Electric Shock Hazard Labels

DANGER

HIGH VOLTAGE

**IF INTERLOCK IS DEFEATED
PERSONNEL MAY BE EXPOSED
TO ELECTRIC SHOCK**

DANGER

HIGH VOLTAGE

**DISCONNECT POWER AND WAIT
5MIN. BEFORE SERVICING**

DANGER

**HIGH
VOLTAGE**

Aperture Labels

AVOID EXPOSURE
HAZARDOUS ELECTROMAGNETIC
RADIATION IS EMITTED FROM THIS
APERTURE.

AVOID EXPOSURE
LASER RADIATION IS EMITTED
FROM THIS APERTURE.

AVOID EXPOSURE
VISIBLE AND/OR INVISIBLE
LASER RADIATION IS EMITTED
FROM THIS APERTURE.

AVOID EXPOSURE
HAZARDOUS X-RAYS
ARE EMITTED FROM
THIS APERTURE.

Labels for Non-Interlocked Protective Housings

CAUTION LASER RADIATION WHEN OPEN. DO NOT STARE INTO BEAM.	DANGER LASER RADIATION WHEN OPEN. AVOID DIRECT EXPOSURE TO BEAM.
CAUTION LASER RADIATION WHEN OPEN. DO NOT STARE INTO BEAM OR VIEW DIRECTLY WITH OPTICAL INSTRUMENTS.	DANGER LASER RADIATION WHEN OPEN. AVOID EYE OR SKIN EXPOSURE TO DIRECT OR SCATTERED RADIATION.
CAUTION HAZARDOUS X-RAYS WHEN OPEN.	CAUTION HAZARDOUS ELECTROMAGNETIC RADIATION WHEN OPEN

Labels for Interlocked Protective Housings

CAUTION

DO NOT REMOVE THIS PLATE EXCEPT FOR LASER BEAM AXIS ADJUSTMENT. HIGH VOLTAGE WILL BE SHUT OFF WHEN THIS PLATE IS REMOVED

The Laser Safety and Training Programs

The extent to which various parts of the parts of the programs are applicable to a specific organization depends on the magnitude of the potential laser hazards within that organization. However, it is essential that each laser safety program include sufficient education of personnel in laser safety.

Responsibility and Authority of the Laser Safety Officer. The Laser Safety Officer (LSO) may be designated from among such personnel as the radiation protection officer, industrial hygiene officer, safety officer, laser specialist, or laser operator. The LSO may be a user if there are very few laser operators or if the class of lasers and potential hazards are low. The LSO may be a part-time position when the work load for an LSO does not require a full-time effort.

The LSO will have the authority to supervise the control of laser hazards. Such authority may include, but is not necessarily limited to, the responsibilities described in this section. The LSO will be trained in accordance with the section titled *Training.*

Consultative Services: The LSO will provide consultative services on laser hazard evaluation and controls on personnel training programs.

Regulations: If a safety committee does not exist, the LSO may establish and maintain adequate regulations for the control of laser hazards.

Authority: The LSO will have the authority to suspend, restrict, or terminate the operation of a laser or laser system if the laser hazard controls are deemed to be inadequate.

Records: The LSO will ensure that the necessary records required by the applicable government regulations are maintained. The LSO will also submit to the appropriate medical officer the names of the individuals who operate the laser and who are the subject of accident reports. 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.

Protective Equipment: The LSO will approve, before use, all protective equipment that will be used in the control of laser hazards.

Surveys and Inspections: The LSO will survey by inspection, as considered necessary, all areas where laser equipment is used. The LSO will also accompany regulatory agency inspectors for laser equipment, such as OSHA, FDA/BRH, and state agencies, and document any discrepancies noted. The LSO will ensure that corrective action is taken where required.

Review of Planned or Modified Laser Installations: The LSO will review new installations and modifications to installations that may increase the hazard to personnel or increase the classification of lasers, to ensure that the hazard control measures are adequate.

Accidents: On notification of a known or suspected accident resulting from the operation of a laser, the LSO will investigate the incident and initiate appropriate action. This may include the preparation of reports to applicable agencies such as those listed previously in this section under *Surveys and Inspections.*

Approval of Laser System Operation. Approval of laser or laser system operation will be given only if the LSO is satisfied that the laser hazard control measures are adequate. The measures include special operating procedures for maintenance and service operations within enclosed systems and operating procedures for Class 3 and Class 4 Systems.

Warning Systems and Signs: The LSO will ensure that adequate warning systems and signs are installed in appropriate locations, and should approve the location and wording of the signs (see the previous pages in this chapter under *Laser Safety Signs and Labels Summary.*

Training: The LSO will ensure that adequate training programs are in effect for all employees using the lasers.

Deputy Laser Safety Officers. If necessary, a deputy LSO will be appointed by Management. The deputy LSO will perform the functions of the LSO when the latter is not available.

Safety Committee. If warranted by the magnitude of the potential hazards of laser operation within the organization, a Safety Committee may be formed.

Membership: The membership may include individuals with expertise in laser technology or in the assessment of laser hazards. Management may be included within the membership. Examples of members include, but are not limited to: technical manager, LSO or other representatives from the Safety Department, and physician and user representatives.

Policies and Practices: The Committee will establish and maintain adequate policies and regulations for the control of laser hazards and recommend the appropriate laser safety training programs and materials.

Standards: The Committee will maintain an awareness of all applicable new or revised laser safety standards. This awareness may require liaison with regulatory agencies, either directly or through representatives.

Responsibilities of the Laser or Laser System Supervisor. The Supervisor will be knowledgeable about the education and training requirements of laser safety, the potential laser hazards and associated control measures for all lasers and laser systems, and all procedures pertaining to laser safety at locations under the Supervisor's authority.

Indoctrination: The Supervisor will be responsible for the issuance of appropriate instructions and training materials on laser hazards and their control to all personnel who may work with lasers that are operated within the Supervisor's jurisdiction.

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 Schedules to Work With Lasers: The Supervisor will submit the names of individuals scheduled to work with lasers to the LSO. In addition, the Supervisor 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 the Supervisor's authority, the Supervisor will immediately notify the LSO or other designated authority.

Medical Attention: If necessary, the Supervisor will assist in obtaining appropriate medical attention for any employee involved in a laser accident.

Approval of Laser System Operation: The Supervisor will not permit operation of a new or modified laser under the Supervisor's authority without the approval of the LSO.

Approval of a Planned Installation: The Supervisor will ensure that plans for laser installations, or modification of installations, are submitted to the LSO for approval.

Operating Procedures: The Supervisor will be familiar with operating procedures for Class 3 and Class 4 lasers and laser systems, and ensure that they are provided to the users of such lasers and laser systems.

Responsibilities of Employees Working With or Near Lasers.

Authorizations: An employee will not energize a laser, nor work with or near it, unless authorized to do so by the Supervisor for that laser.

Compliance: An employee will comply with the rules and regulations prescribed by the Supervisor and the LSO. The employee will be familiar with all operating procedures.

Accident Reporting: When an employee who is operating a laser knows or suspects that an accident has occurred involving that laser, or a laser operated by any other employee, and that such accident has caused an injury or could potentially have caused an injury, that employee will immediately inform the Supervisor. If the Supervisor is not available, the employee will notify the LSO.

Eye Examinations: The employee shall:

- Report for an initial eye examination *before* working on or in the vicinity of an Nd:YAG laser.
- Report for an eye examination immediately following eye exposure, or suspected exposure, to laser radiation

Training. Training will be provided to each employee who is routinely working with, or in the vicinity of, lasers above Class 2. The level of training will be commensurate with the degree of potential hazards.

CHAPTER 3

WORKING WITH THE LASER SYSTEM

Overview

Please review this chapter thoroughly prior to installing and attempting to operate Amada Weld Tech Laser systems. The safety precautions included in this chapter must be carefully followed to ensure that all personnel who install, operate, service or maintain laser equipment are protected from accidental or unnecessary exposure to laser radiation.

> ***WARNING:*** When the laser unit is not in use, remove the control switch key to prevent use of the laser by unauthorized personnel.

Operation, Maintenance and Service Functions

Laser products are classified according to the maximum level of laser radiation to which human access is possible during *operation.* The class of the product is not affected by the level of laser radiation accessible during *maintenance* or *service*.

> ***WARNING:*** The laser user is responsible for ensuring that appropriate safety precautions as defined in this manual and ANSI Z136.1 are followed while these functions are being performed. *Failure to follow these warnings can result in personal injury.*

Operation. The term “operation” means the performance of the laser product over the full range of its functions. It does not include maintenance or service. Examples of “operation” include loading work pieces, and adjusting and operating system controls.

Maintenance. The term “maintenance” consists of functions performed to assure satisfactory performance of the laser product. This means performance of those adjustments or procedures specified in the equipment user’s manual that are to be performed by the user for the purpose of assuring the intended performance of the product. This includes cleaning the optics and replacing expendables. Normally, there is no requirement to run the laser during maintenance functions.

Service. The term “service” consists of functions to restore the capability of the product to perform its intended purpose. This means the performance of those procedures or adjustments described in the service instructions. This includes repair or replacement of defective components, alignment of optical components and adjustments to the fixturing. Some service functions normally require operation of the laser.

21 CFR 1040.10 Compliance Requirements

The Amada Weld Tech Laser System incorporates the following safety features required by Title 21, Code of Federal Regulations, Subchapter J, (21 CFR). These features are essential to the classifications of the laser system as a certified laser product. *Modification or use of the Amada Weld Tech Laser System in any way that changes the design or function of these safety features invalidates the certification of the laser by Amada Weld Tech and subjects the user to the compliance and certification requirements imposed upon laser manufacturers by 21 CFR.*

> ***WARNING:*** The use of controls or adjustments, or the performance of procedures, other than those specified in the equipment user's manual, may result in exposure to hazardous radiation.

Amada Weld Tech designs and produces laser systems to be in compliance with Federal standards. They are certified for safe operation when the following required features are properly used:

- The optical cavity is enclosed within a protective housing which physically prevents access to laser radiation at any point along the beam path except where it exits the output at the work piece. The door or cover providing access to the housing is interlocked so that the laser shuts down when the door is opened. This prevents access to both laser radiation and high voltage inside the optical cavity. Never operate the laser with these doors open and the interlocks defeated except during a required function such as optical alignment as performed by qualified service personnel.
- The protective laser housing and any work enclosure are fitted with interlocks designed to shut down the laser when the interlocks are activated during operation or maintenance. These interlocks prevent closure of the laser cabinet when the interlocks are defeated. The interlock switches are rated by the manufacturer to be operationally reliable for at least 200,000 actuations. To ensure continued safe operation, the interlocks should be replaced when they reach their rated life.
- The laser control panel and other operating controls are located in such a way that exposure to laser radiation is not required during operation.
- Certification and warning labels are affixed to the laser system to assure the user that it complies with 21 CFR 1040 and to warn the user against accidental exposure to laser radiation.
- Instructions for safely operating, maintaining and servicing the Amada Weld Tech Laser Systems are provided in the user's manuals for the systems. Carefully read the instructions. If you have questions concerning this information, or if you find errors or omissions, please contact the factory at:

Amada Weld Tech Inc.
1820 South Myrtle Avenue
Monrovia, CA 91016
Telephone: (626) 303-5676
FAX: (626) 358-8048

- At least one safety shutter is mounted in the optical cavity between the laser head and the output optic to interrupt lasing when necessary. The shutter is actuated by a switch on the laser control panel. The shutter has been rated by the manufacturer to be reliably operational for 1,000,000 actuations. To ensure continued safe operation of the laser, replace the shutter when it reaches its rated life.
- The laser cannot be turned on without the master key to operate the key control. This is to assure that only trained personnel have access to the laser.
- An emission indicator is located on the laser control panel. It lights when the master control key switch is turned on to indicate that the laser is being readied for emission of laser radiation. The indicator lights prior to actual emission to give nearby personnel time to avoid exposure to laser radiation. It remains on as long as the laser is capable of lasing.
- Laser-safe eyewear attenuated to the wavelength of 1064 nanometers (and 632.8 nanometers when the optional He-Ne alignment laser is installed) with a minimum optical density (OD) of 6 should be worn at all times when servicing Amada Weld Tech Laser Systems.
- Amada Weld Tech Laser Systems comply with the requirements of 21 CFR 1040.10. The class of laser system is identified on labels attached to the system itself. Verification of compliance may be obtained from:

U.S. Food and Drug Administration
Centers for Devices and Radiological Health
10903 New Hampshire Avenue
Silver Spring, MD 20993-0002

ANSI Z136.1, American National Standard for the Safe Use of Lasers, is published by the American National Standards Institute, 1430 Broadway, New York, NY 10018, (212) 354-3300 and provides information on the compliance requirements for users of laser equipment. ANSI Z136.1 is used by OSHA, the Occupational Safety and Health Administration, as its standard when inspecting facilities where lasers are in use.

The Laser Institute of America also provides information regarding the safe use of lasers. You may contact the Institute at:

12424 Research Parkway, Suite 130
Orlando, FL 32826
(407) 380-1553.

Practical Laser Safety (New York: Marcel Dekker, 1985) by D.C. Winburn, provides an excellent review of current laser safety practices for the industrial environment.

It is recommended that the position of Laser Safety Officer, as defined in the *ANSI Z136.1* standard, be established in any company which uses industrial lasers. This person should be trained in laser safety and given the authority to control the operational environment of the laser systems being used. More information is available from the Laser Institute of America or Amada Weld Tech.

Safety Precautions

The safety precautions in this chapter have been prepared to assist you in practicing good system safety procedures. Personnel should read and thoroughly understand these precautions before installing, setting up, operating, maintaining or servicing the system.

These precautions are to be used as a guide to supplement the safety precautions and warnings contained in the following:

- All other manuals pertaining to the system or system components.
- Local, plant and shop safety rules and codes.
- Federal and national safety laws and regulations. See the latest edition of the Occupational Safety and Health Standards available from the Department of Labor, Washington D.C.
- Read all safety precautions before operating the system. Failure to follow safety instructions may result in personal injury and/or damage to the equipment.

Safety Rules

Personnel must be constantly aware that day-to-day safety procedures are a vital part of their job. Accident prevention must be one of the primary objectives of the job regardless of what activity is involved. The following suggestions will help avoid accidents:

- Be alert, safety minded and avoid “horseplay” in the work area.
- Understand and follow all plant safety rules and signs.

- X Look for and immediately report all unsafe conditions.
- X Wear laser safety goggles having the recommended optical characteristics for your system.
- X Wear standard clear acrylic or polycarbonate safety goggles when working in the vicinity of moving plant equipment.
- X Wear safety-toe shoes with slip resistant soles.
- X Restrain long hair with a cap or net.
- X Wear gloves only when they are essential to the job.
- X Wear a safety hat if the job requires one.
- X Do not wear neckties, scarfs, loose hanging clothing or jewelry such as watches, rings or necklaces.

Work Area Safety

Keep the work area clean. Do not allow oil, debris or water to accumulate on the floor. Such hazards may cause someone to fall to the floor, into moving mechanisms or against other objects and result in injury.

Be aware that it is possible for mechanisms to move unexpectedly whenever the system is operating. Unexpected movement can be caused by the control program, human error or a system malfunction.

Physical contact with a moving mechanism may result in a personal injury. Personnel not qualified to operate or service the system must not enter the area when the system is ON.

Warning signs, a painted stripe on the floor, a flashing red light and restrictive devices such as chains or walls must be maintained around the working mechanisms of the system. The warning signs must indicate hazardous conditions and the consequences of disregarding the warnings.

The interlock system of the laser must be used and maintained. Peripheral equipment, safety panels, doors and warning lights are wired into the interlock circuit to maintain a high level of personnel protection while the laser is operating.

Electrical Safety

- X Never work on electrical equipment unless another person is present.
- X Disconnect main power to the laser when a repair or service function to be performed does not require the laser to be on.
- X Capacitors used in the laser system can store electrical energy. Wait at least ***5 minutes*** after disconnecting the power before proceeding. Then use a discharge rod to test the circuit ***before*** touching any electrical components.

X Become familiar with the system's electrical circuits before attempting to work on the laser. Schematics are provided with each laser. Only trained, qualified personnel should be allowed to work on the laser.

X Always use approved, insulated tools.

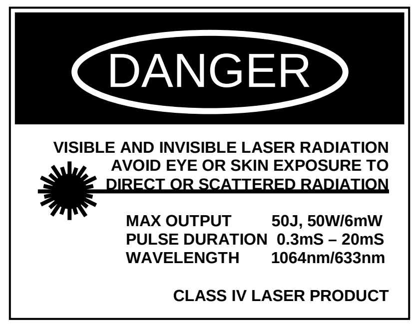
System Hazards

Hazards associated with laser systems generally fall into the following categories:

> ***WARNING:*** Do not attempt to work with lasers until you have had proper training. You must understand the hazards involved and know how to avoid them.

X Eye or skin hazards resulting from exposure to laser radiation. The type of damage is dependent on the wavelength of the particular laser.

X The Nd:YAG laser is in the infrared zone and has a wavelength of 1.064 microns (1064 nanometers).



X When in the vicinity of a laser in operation, wear protective goggles having a minimum optical density of 6 at the wavelength of 1.064 microns (1064 nanometers).

X Do not allow unrestricted emission of the laser beam. Block it with a heat-resistant material (stopper) that absorbs the laser beam.

X Make sure that the laser beam never touches the skin.

X Chemical hazards released as a result of laser material processing or as a byproduct of the lasing process itself. Certain metals and plastics give off extremely toxic fumes that must be properly ducted and disposed of when processed using a laser beam. The hazard is generally due to the thermal nature of the process.

X Electrical hazards from the high voltage present in the laser power supply or associated circuits.

- < Study the schematics and read the servicing materials provided in the user's manual prior to any attempt to service or repair the laser unit.
- < When replacing the flash lamp or removing the power supply cover, turn off the power and wait for at least 5 minutes before proceeding.
- < Be sure that the laser unit ground terminal is securely connected to shop power ground.

X Fire hazards. To avoid the risk of fire, do not apply the laser beam to combustible or flammable materials.

X Secondary hazards such as:

< X-ray radiation from faulty power supplies.

< High noise levels.

< Pressurized containers such as lamps, hoses, cylinders.

< Moving parts in material handling systems.

< EMI/RFI emissions from faulty equipment.

< Pressurized liquids and gases.

Environmental Precautions

Normal Temperature and Humidity Ranges. The work place for the laser unit should be kept at a steady temperature of 5° to 35°C (41° to 95°F) and a humidity level of 85% maximum. Do not operate the laser where it might be exposed to:

X Temperature and humidity outside the ranges specified

X Considerable dust, dirt, chemical vapors or oil mist

X Vibration or shock

X High-frequency sources

Cold Weather Operation. Observe the following when operating the laser in cold weather:

X Maintain an ambient temperature above freezing to avoid damage to the equipment through freezing of the water coolant.

X Avoid rapid temperature variations. They could cause dew to form on the end surfaces of the YAG laser rod and the optical fibers. The dew could contaminate the surfaces and lead to damage. If you suspect the presence of dew, examine the end surfaces of the YAG rod and fiber optics before firing the laser.

Optical Fiber Precautions

Do not subject the optical fibers to strong shock or sharp bends. Maximum bend radii for various core diameters are listed in Table 3-1.

Table 3-1. Optical Fiber Maximum Bend Radii

Core Diameter (mm)	Maximum Bend Radius (mm)
0.2	100
0.4	100
0.6	150
0.8	200
1.0	250

Handling the Laser Unit

Safety Supervisor. Appoint a Safety Supervisor for all laser work. The appointed Safety Supervisor must have sufficient training and experience relating to lasers and laser work. He or she must be responsible for instructing operating and maintenance personnel in the safety aspects of their job and for directing the work.

Key Switch. The laser unit can be secured from operation with its key switch. The key switch should remain in the custody of the Safety Supervisor.

Operation. Read the user's manual thoroughly before operating the laser unit. Place a shield around the work piece to avoid injury or fire.

Design Integrity. Do not modify the laser unit. It has many components that operate at high voltages, and changing these components can be dangerous.

Transporting the Laser Unit. For transportation, the oscillator head in the Nd:YAG Lasers are secured with shipping brackets. Be sure that these brackets are secure during transportation and removed before operation. Refer to the appropriate Operators Manual for more information.

Fiber Lasers are best transported by putting the Laser back in the appropriate shipping container, taking care to not bend the optical fiber past its bend radius (see table above). Refer to the appropriate Operators Manual for more information.

AMADA WELD TECH INC.

http://www.amadaweldtech.com

AMADA WELD TECH INC.

1820 South Myrtle Ave., Monrovia, CA 91016, U.S.A.
TEL. +1-626-303-5676 FAX, +1-626-358-8048
http://www.amadaweldtech.com

AMADA WELD TECH CO., LTD.

200, Ishida, Isehara-shi, Kanagawa 259-1196, Japan

AMADA WELD TECH KOREA CO., LTD.

28, Dongtanhana 1-gil, Hwaseong-si, Gyeonggi-do, 18423, Korea
TEL. +82-31-8015-6810 FAX. +82-31-8003-5995

AMADA WELD TECH SHANGHAI CO., LTD.

Unit 401, A206(C8), No. 77, Hongcao Road, Xuhui District, Shanghai, China
TEL. +86-21-6448-6000 FAX. +86-21-6448-6550

AMADA WELD TECH GmbH

Lindberghstrasse 1, DE-82178 Puchheim, Germany
TEL. +49-89-839403-0 FAX. +49-89-839403-68

AMADA WELD TECH TAIWAN CO., LTD.

Rm. 5, 2F., No. 9, Dehui St., Zhongshan Dist., Taipei 10461, Taiwan (R.O.C.)
TEL. +886-2-2585-0161 FAX. +886-2-2585-0162

AMADA VIETNAM CO., LTD.

469 Ha Huy Tap Road, Yen Vien, Gia Lam, Ha Noi, Vietnam
TEL. +84-4-6261-4583 FAX. +84-4-6261-4584

AMADA (THAILAND) CO., LTD.

Asia Industrial Estate Suvarnabhumi (AIES) 88/41 Moo 4, Khlongsuan, Bangbo, Samutprakarn 10560, Thailand
TEL. +66 2170-5900 FAX. +66 2170-5909

AMADA WELD TECH INDIA PVT. LTD.

G-A Ground Floor, 5C-409, 5th Cross, Kammanahalli Main Road, HRBR Layout, Kalyan Nagar, Bengaluru, - 560043, India
TEL. +91-80-4092-1749 FAX. +91-80-4091-0592

AMADA WELD TECH LTDA.

Av. Tamboré, 965/973, Salas P22e F11, bairro Tamboré, 06460-000-Barueri-SP, Brazil
TEL. +55-11-4193-1187

AMADA WELD TECH INC.
1820 South Myrtle Ave., Monrovia, CA 91016, U.S.A.
TEL. +1-626-303-5676 FAX. +1-626-358-8048