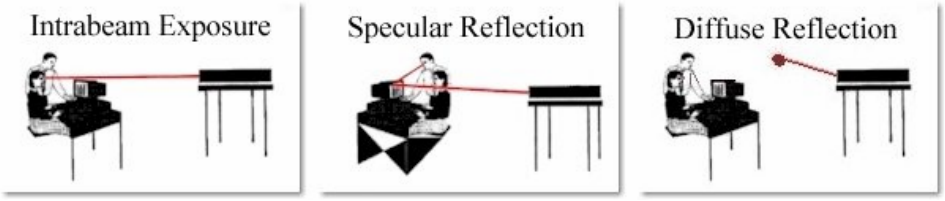
LASER SAFETY

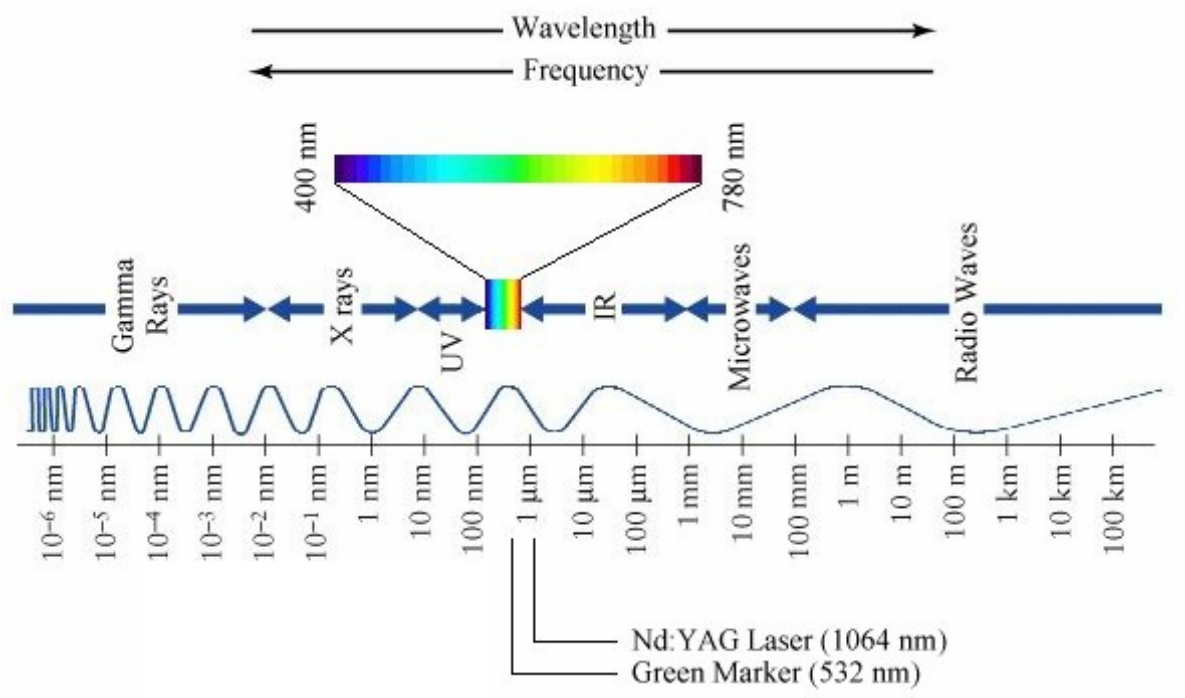
One of the most important issues regarding the use of all lasers is the ability to operate the laser equipment in a safe manner. In the United States, the CDRH (Center for Device Radiation Hazards) department of the FDA (Food and Drug Administration) has jurisdiction over laser safety issues. In particular, CDRH oversees the implementation of all safety features in laser equipment. The specific requirements can be found in the Code of Federal Regulations, Title 21, section 1040.10 and 1040.11. Additional information concerning machine design for laser safety can be found in ANSI A136.1

All lasers sold by Miyachi Unitek are CDRH compliant and are safe to operate when used properly. Aside from the nominal hazards associated with operating any piece of equipment, the main hazard associated with using Nd:YAG or Nd:YVO_4 welding and marking lasers relate to the direct or indirect exposure of the eyes and skin to the laser radiation.

Damage to the eye and skin can occur through different types of exposure:



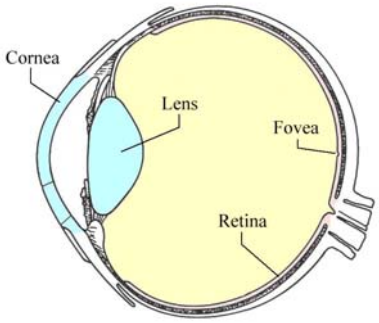
Therefore, just because the laser beam is not pointing directly at you, does not mean that you are safe from exposure. All of the Miyachi Unitek Laser Welders produce 1064nm (in the NIR, near infrared range) and all Laser Markers produce either 532nm (visible) or 1064nm (NIR). When looking at the complete wavelength spectrum, the 1064nm and 532nm wavelengths reside in or near the visible region as shown below:



Eye Damage

Eye damage and skin burns are the main problem with lasers that produce the 1064nm wavelength, which is outside of the visible region. The eyes cannot react to the intense laser beam the same way the eye would react to a high intensity light in the visible region. If the laser beam enters the eye, the pupil will not react and will allow all of the laser energy to enter the eye. The type of eye damage is wavelength dependent.

Wavelength	Damage to
$290 < \lambda < 400$nm (Ultra-violet (UV))	Cornea and/or lens
$400 < \lambda < 1{,}400$nm (visible and NIR)	Retina (Fovea)
$1400 < \lambda < 10{,}600$nm (Far Infrared)	Cornea and/or lens



In order to operate the lasers in a safe manner, the operator must always work in a Class I "eye safe" environment. There are four levels of laser classes, Class IV to Class I, with Class I being the safest. A Class I environment is achievable by wearing laser safety goggles/glasses or containing all of the laser radiation in a light sealed Class I enclosure/workstation. CDRH provides laser manufacturers and users with specific rules, standards and exposure limits for each type of laser and power level. These rules must be strictly adhered to. All Lasers are divided into classes based on their capability of producing injury.

Class	Condition	Examples
I	Safe from all potential hazards.	MUC Workstations, Laser Printers, CD Players
II	Laser emits a visible beam with output power $\leq$ 1mW. Safe to use with normal eye inversion.	Laser pointers, CW HeNe lasers
IIa	Laser emits a beam with output power $\leq$ 1mW, but is not intended to be viewed directly. Damage can occur with exposure > 1000 hours.	Bar Code Readers
IIIa	Laser emits medium output power ($1\text{mW} \leq P_{OUT} \leq 5\text{mW}$) No hazard if viewed momentarily with the unaided eye.	Solid state lasers, CW HeNe lasers.
IIIb	Laser emits medium output power ($5\text{mW} \leq P_{OUT} \leq 0.5\text{W}$) These types of lasers will produce eye damage if viewed directly. Interlocks and protective wear must be implemented.	Small industrial lasers
IV	Laser emits high output power ($\geq$ 0.5W) or energy density greater than 10J/cm^2 for a 0.25 second period. These lasers will produce eye, skin and fire hazards. This includes intrabeam viewing, specular reflections or diffuse reflections. Interlocks and protective wear must be implemented.	Industrial lasers

Class I Environment

As described above, in order to operate the laser in a safe manner, it must be operated in a Class I environment. All lasers sold by Miyachi Unitek are registered Class IV equipment. All operators and surrounding people must be protected from laser emissions. The easiest way to provide a Class I environment is to use Laser Safety Goggles/Glasses when operating the laser. In addition the laser should be isolated in a laser-controlled environment away from all other workers (through the use of workstations, light curtains, isolated rooms, etc.).

Laser Safety Goggles/Glasses

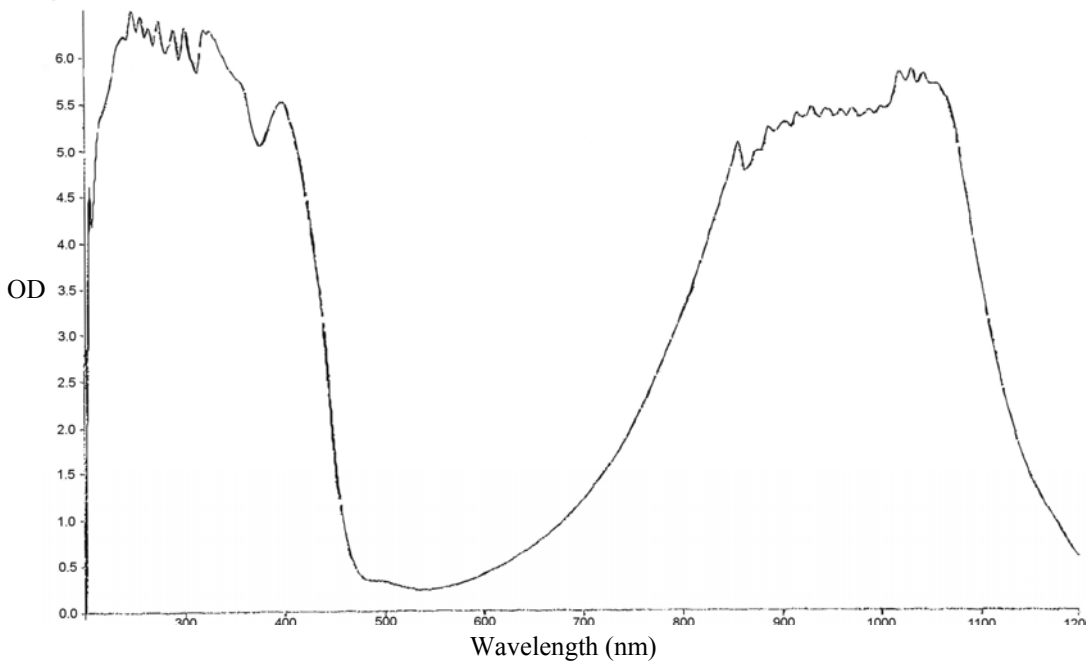
There are many manufacturers of Laser Safety Goggles/Glasses. The two parameters of interest are the *Spectral Response* and the *Optical Density* (OD). The OD defines the amount of protection and is a calculated from the ratio between the incident and transmitted power. The OD is defined as:

$$\text{OD (optical Density)} = \text{Log}_{10} \frac{P_{INCIDENT}}{P_{TRANSMITTED}}$$

Choose safety glasses that will protect your eyes from the emitted wavelength (spectral response) and that have a high optical density at the emitted wavelength. In general choose an optical density of 5 or greater at your operating wavelength. The higher the optical density, the better the protection. Miyachi Unitek uses and recommends UVEX Laser Safety Glasses.

Wavelength (λ)	Uvex Pt #	Protection	Glass Color
1064nm	LSK-YAG/CO2	OD = 7^{+} at 1064nm	Green
532/1064nm	LSK-YAG/KTP	OD = 7 at 532nm OD = 7 at 1064nm	Orange

The safety glasses may be purchased either through Uvex or through Miyachi Unitek. A typical spectral response of the laser safety glasses is shown below:



Other Laser Hazards

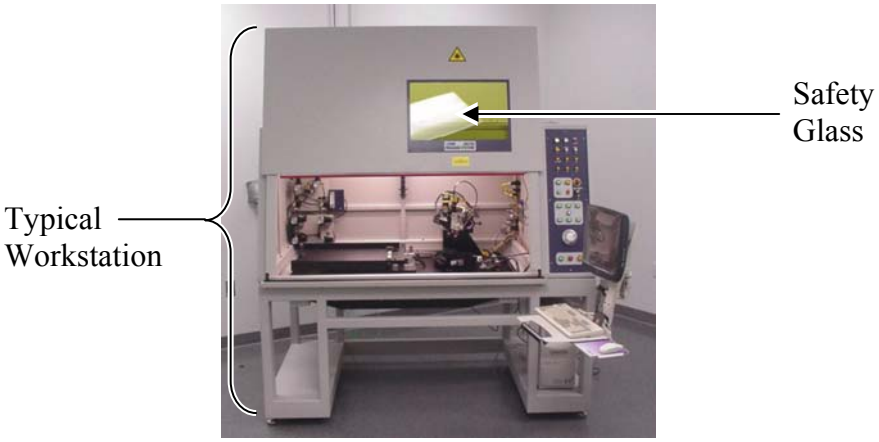
In addition to the eye and skin damage that can be done with lasers, there are other hidden dangers that must be understood.

- Whenever a laser is used to weld or mark materials, airborne contaminants are emitted from the workpiece. The use of a fume extractor is a must, especially when working with plastics, as many plastics give off toxic fumes when heated.
- The laser is also capable of causing a fire, due to the high energy densities emitted from the laser. A laser should NEVER be used in the presence of flammable materials, chemicals or solvents.
- Lethal voltages (≥ 4.5kV) are also present behind the laser panels and present a lethal shock hazard. Never service or modify the laser when powered "ON".
- When welding metals, ultra-violet (UV) radiation is emitted from the welding plume and can cause eye damage. Operators should never look in the general direction of the weld point.

Workstation Laser Safety

Laser safety goggles/glasses are used primarily when the laser operator is working with the laser in open surroundings. Many systems shipped from Miyachi Unitek, some third party systems and integrators package the laser in a Class I workstation, which keeps the NIR laser emissions from reaching the operator and others in the surrounding areas.

Most workstations would be useless without some sort of viewing window. The window cannot be made of typical clear glass, because all laser emissions can pass through the glass. Instead a wavelength dependent coated glass must be used. The workstation safety glass is chosen the same basic way as the laser safety goggles/glasses. Miyachi Unitek uses and recommends *Lase-R Shield* safety glass (www.lase-rshield.com). A typical application for safety glass is shown below:



Safety Interlocks

All lasers shipped from Miyachi Unitek are equipped with a safety interlock circuitry. The interlock circuitry is made up of multiple momentary switches connected in series. (CDRH rules require redundant interlock switches.) In order for the laser to operate correctly, the "Interlock Circuit" must be *closed*. If the laser is firing and the "Interlock Circuit" is *opened*, the shutter(s) will close and cut-off all laser light. This is the easiest and most effective safety feature to implement. Refer to the External I/O section of your Laser User's Manual for more information.