

LASER SAFETY



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NEED

- As our use of lasers increases, we have a tendency to think of them as commonplace, and we begin to forget that these small, often invisible light sources are able to cause permanent damage to our eyes.



POOR WALL!!!

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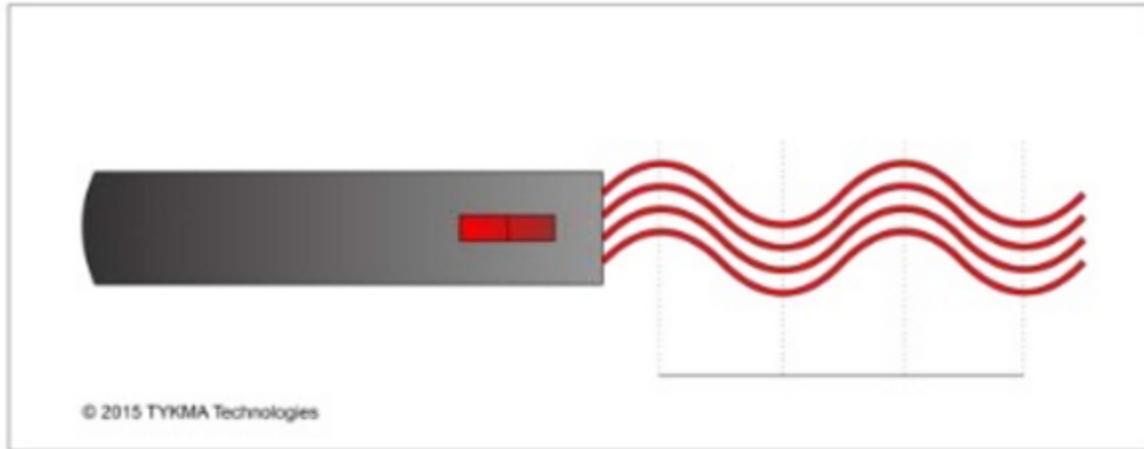
NEED FOR LASER SAFETY



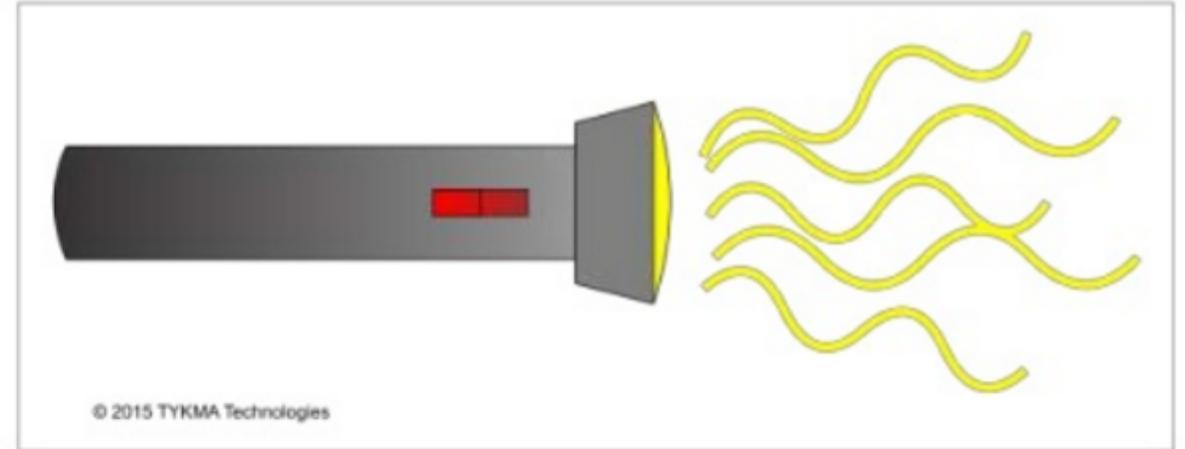
- Exposure to laser light can cause significant damage to the skin and eyes – typically in the form of burns and direct damage to the retina.

Laser Light vs. Ordinary Light

A laser emits light that is unidirectional and composed of a single wavelength.



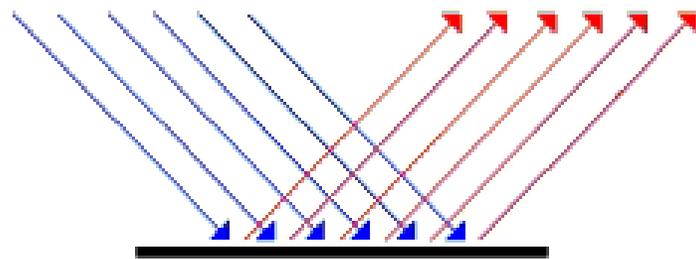
A flashlight emits light that is multi-directional and composed of many different wavelengths.



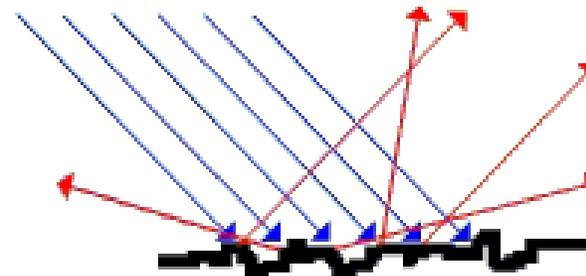
As a result laser light can be focused to a small spot (0.010" or smaller) allowing applications such as marking, engraving, cutting and welding to be easily performed.

EXPOSURE TO LASER LIGHT

- **Primary beam:** Direct hit/exposure from primary beam. This is the most hazardous.
- **Specular reflection:** Exposure from laser hitting a shiny/smooth surface. This can be as hazardous as the primary beam.
- **Diffuse reflection:** Exposure from a rough object.



Specular Reflection
(smooth surfaces)



Diffuse Reflection
(rough surfaces)

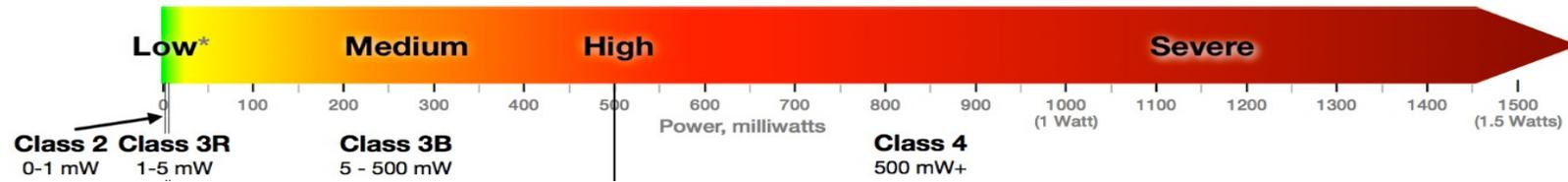
Laser Classification

Power/Energy of the Laser Beam

Wavelength of the emitted radiation



**ONLY VALID FOR
VISIBLE RADIATION**



Class	Procedure	Training	Eye Exam	Energy	Hazard
1	Not Required	Not Required	Not Required		Non-hazardous to eye
1M	Not Required*	Not Required*	Not Required		Hazardous with collecting optics
2	Not Required	Not Required	Not Required	< 1mW	Hazardous only when person overcomes aversion response
2M	Not Required*	Not Required*	Not Required		Hazardous with collecting optics and/ Class 2 hazard
3R	Not Required	Not Required	Not Required	1 - 5mW	Hazardous when person overcomes aversion response or uses optics
3B	Required	Required	Suggested	5 - 500mW	Direct beam eye hazard. No serious injury from diffuse reflection to eye or to skin
4	Required	Required	Suggested	> 500mW	Hazard to eye & skin from direct, specular or diffuse reflection. Fire hazard

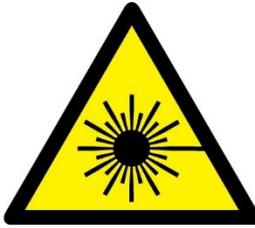
WARNING LABELS

CAUTION

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

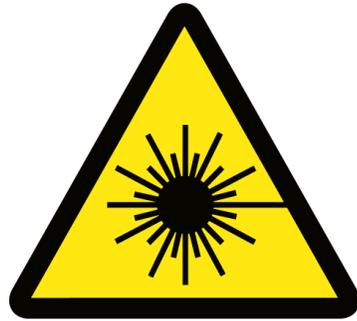


CLASS I LASER PRODUCT



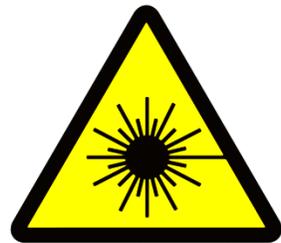
Laser radiation
CLASS 2
laser product

**Do not stare
into beam**



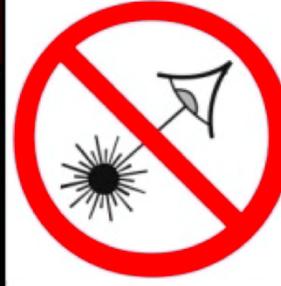
! DANGER

CLASS 3B LASER RADIATION.
AVOID DIRECT EXPOSURE
TO THE BEAM.
DO NOT DISCONNECT
WHILE SYSTEM IS ACTIVE.



! DANGER

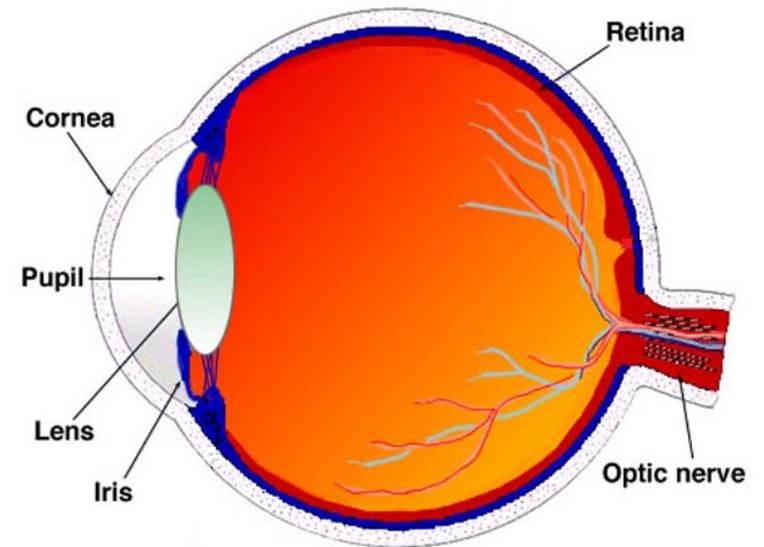
**CLASS 4
LASER
PRODUCT**



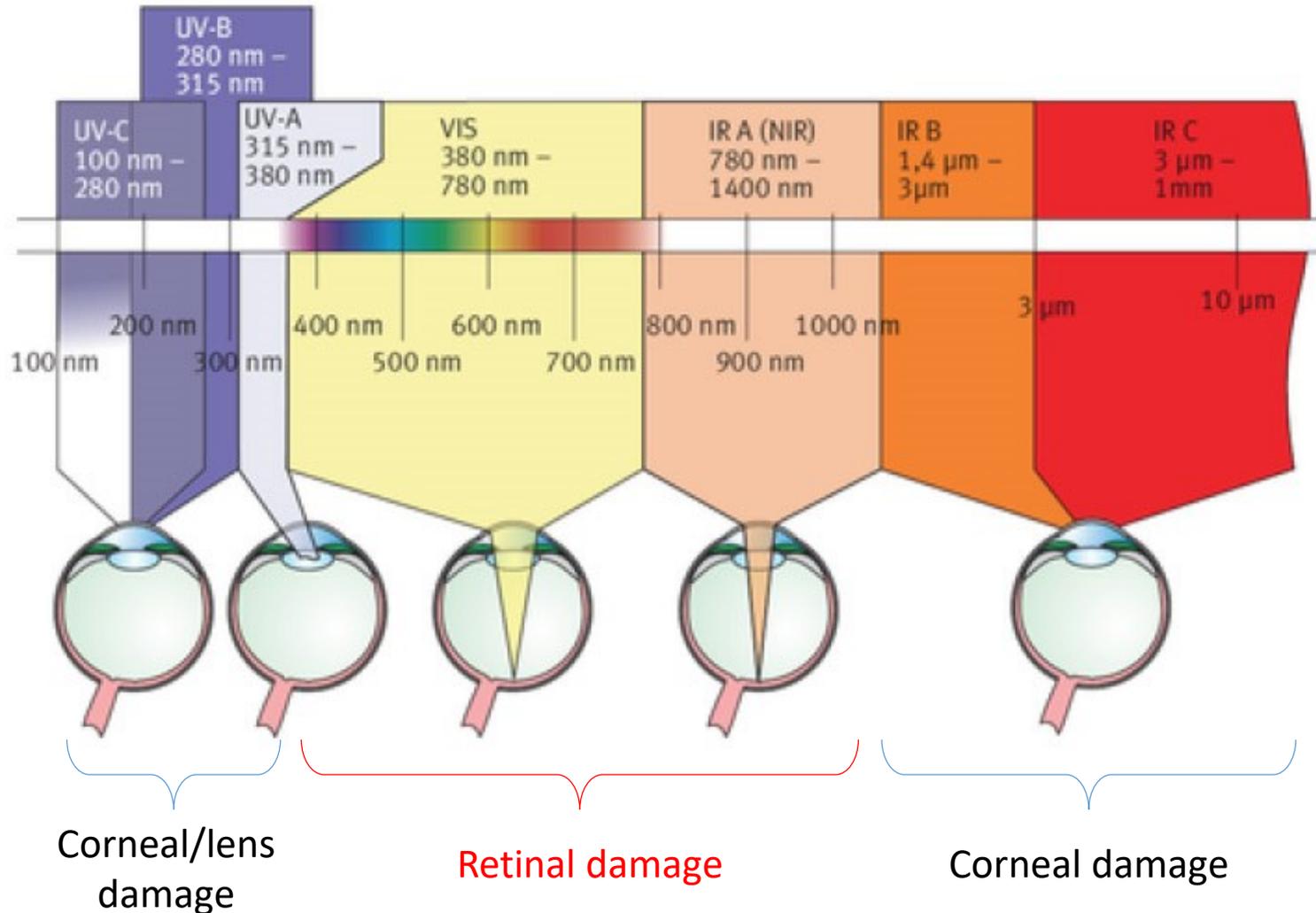
**AVOID EYE OR SKIN EXPOSURE
TO DIRECT OR SCATTERED LASER LIGHT
NEVER AIM AT AIRCRAFT - IT IS UNSAFE AND ILLEGAL**

WHY WAVELENGTH MATTERS?

- Laser wavelengths **longer than 1400 nm & shorter than 380 nm** are strongly absorbed in the cornea and lens, not retina
 - So damaging energy levels often do not reach the retina.
- Lasers producing light in this range, below a certain power threshold, are “retina safe.”
 - **But still not “eye-safe”!**
- Retina safe wavelengths allow for higher exposures (longer exposure time and/or higher power) before there is any permanent damage to the eye.
 - **But let us not test the ability of cornea to heal**



RESPONSE OF HUMAN EYE TO DIFFERENT WAVELENGTHS OF LIGHT



Retina damage is often permanent and irreparable.

Cornea and lens damage can heal, although the injury is incredibly painful.

RESPONSE OF HUMAN EYE TO DIFFERENT WAVELENGTHS OF LIGHT

- The cornea and lens absorb the laser energy, causing them to heat.
- Typically, the damage (if any) at higher/lower wavelengths will be to the cornea.
- The amount of the heat, as well as potential damage, depends not only on the wavelength, but also on the power, beam divergence, beam quality, and length of exposure.

PERSONAL PROTECTIVE EQUIPMENT

EYE PROTECTION

- Appropriate eye protection devices must be worn when working with Class 3B and Class 4 lasers or laser systems.
- Eyewear must be specifically selected to withstand either direct or diffusely scattered beams
- Goggles are marked with the wavelength range over which protection is afforded and the minimum optical density within that range.



PICKING THE APPROPRIATE LASER SAFETY GLASSES – ANSI Z136 Standard

- The correct choice of laser safety eyewear depends upon many local factors that must be evaluated on case-by-case basis, including **the beam path, laser parameters, and lab environment.**
 - Discuss your needs with your supervisor/manager
- Common safety standard is ANSI Z136
- Uses OD to represent the opacity of the glasses

$$OD = \log_{10} \frac{1}{T} \quad \text{or} \quad T = 10^{-OD}$$

OD = Optical Density

T = Transmittance (decimal)

OD	Transmittance	OD	Transmittance
0.0	100%	5.0	0.001%
1.0	10%	6.0	0.0001%
2.0	1%	7.0	0.00001%
3.0	0.1%	8.0	0.000001%
4.0	0.01%	9.0	0.0000001%

PICKING THE APPROPRIATE LASER SAFETY GLASSES – EN207 Standard

- More comprehensive than ANSI standard.
- Provides an LB-Rating which has 3 components:
 - Wavelength range,
 - Laser mode designation, and
 - Scale number (LBn)
- The scale number (LBn) is used with wavelength range and laser mode to determine minimum required level of protection
 - See table

Laser Mode	Engraved Symbol	Pulse Duration
Continuous Wave (CW)	D	>0.25 s
Pulsed Mode	I	>1 μ s - 0.25 s
Giant Pulsed Mode	R	1 ns - 1 μ s
Mode Locked	M	< 1ns

Wavelength	Laser Mode	Maximum Power Density (P) or Maximum Energy Density (E)	Minimum Scale Number (LBn)
180 - 315 nm	D	$1 \times 10^{n-3} \text{ W/m}^2$ ($1 \times 10^{n-7} \text{ W/cm}^2$)	$\log_{10}(P)+3$
	I and R	$3 \times 10^{n+1} \text{ J/m}^2$ ($3 \times 10^{n-3} \text{ J/cm}^2$)	$\log_{10}(E/3)-1$
	M	$3 \times 10^{n+10} \text{ W/m}^2$ ($3 \times 10^{n+6} \text{ W/cm}^2$)	$\log_{10}(P)-10$
>315 - 1400 nm	D	$1 \times 10^{n+1} \text{ W/m}^2$ ($1 \times 10^{n-3} \text{ W/cm}^2$)	$\log_{10}(P)-1$
	I and R	$5 \times 10^{n-3} \text{ J/m}^2$ ($5 \times 10^{n-7} \text{ J/cm}^2$)	$\log_{10}(E/5)+3$
	M	$1.5 \times 10^{n-4} \text{ J/m}^2$ ($1.5 \times 10^{n-8} \text{ J/cm}^2$)	$\log_{10}(E/1.5)+4$
>1400 - 1000000 nm	D	$1 \times 10^{n+3} \text{ W/m}^2$ ($1 \times 10^{n-1} \text{ W/cm}^2$)	$\log_{10}(P)-3$
	I and R	$1 \times 10^{n+2} \text{ J/m}^2$ ($1 \times 10^{n-2} \text{ J/cm}^2$)	$\log_{10}(E)-2$
	M	$1 \times 10^{n+11} \text{ W/m}^2$ ($1 \times 10^{n+7} \text{ W/cm}^2$)	$\log_{10}(P)-11$

SKIN PROTECTION

- If potential skin damaging exposures exist, skin covers and or “**sun screen**” creams are recommended.
- Minimize exposure to UV radiation by using **beam shields and clothing** (opaque gloves, tightly woven fabrics, laboratory jacket or coat) which attenuate the radiation to levels below the MPE for specific UV wavelengths.
- Consider **flame-retardant materials** for Class 4 lasers.
- Special attention must be given to the possibility of producing **undesirable reactions in the presence of UV radiation** (formation of skin sensitizing agents, ozone, etc.).

SAFE PRACTICES

Safe practices and proper usage of safety equipment should be taken into consideration when operating lasers.

SAFE PRACTICES

- Use **safety eyewear** whenever working with laser beams with non-negligible powers (i.e., > Class 1)
- Laser **goggles designed for specific wavelengths** should be clearly available near laser setups to protect the wearer from unintentional laser reflections.
- **Laser Safety Curtains, Laser Barriers and Blackout Materials** can prevent direct or reflected light from leaving the experimental setup area.
- Post appropriate **warning signs** or labels near laser setups or rooms.
- **Turn off the laser** before connecting it to or disconnecting it from another fiber.

SAFE PRACTICES (continued)

- All beams should be **terminated at the edge of the table**, and **laboratory doors should be closed** whenever a laser is in use.
- Do not place laser beams at eye level.
- **Carry out experiments on an optical table** such that all laser beams travel horizontally.
- Remove **unnecessary reflective items** such as reflective jewellery (e.g., rings, watches, etc.) while working near the beam path.
- Be aware that **lenses and other optical devices may reflect** a portion of the incident beam from the front or rear surface.
- **Operate a laser at the minimum power necessary** for any operation.
- If possible, reduce the output power of a laser during alignment procedures.

EXERCISE CAUTION

- **Laser Acquisition**

- Use minimum laser radiation required for the application.
- Put a proper warning label (Class 2 and above) on the device and at the location of use.
- This must never be removed or tampered with.

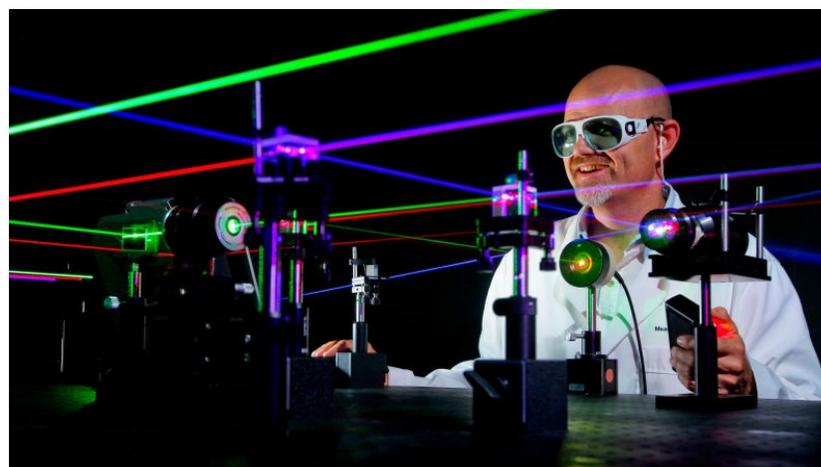
- **Laser Transfer**

- If a laser source doesn't have a warning label, don't turn it ON until its CLASS is known.
- When a Class 3b or 4 laser is transferred, educate the new user about laser safety.

- **Laser Disposal**

- Notify the Head of the 'Green Gang' before you decide to throw away a laser source.
- Proper procedure has to be followed for its disposal.

SUMMARY



**THANK
YOU**



Reference

- rp-photonics.com
- semnex.com
- Laser safety manuals:
 - Stanford
 - MIT
 - Thor Labs

SAFE PRACTICES

In Detail

With Class 1,2 & 3R lasers

When used as intended Class 1, 2, and 3R laser systems are generally low hazard devices; however some requirements still apply.

- **Train** on proper use of that equipment.
- Exposure to laser radiation must be kept below the **Maximum Permissible Exposure** (MPE) under all conditions of operation or maintenance.
- Laser systems must have the **appropriate warning labels** with the laser sunburst logotype symbol and the appropriate cautionary statement.
- **Removal of protective housing or system modification can increase a laser's classification. Beware!!**
- **Use of class 3R laser with telescopes, microscopes, or alignment devices without permission from your supervisor is strongly discouraged.**

With Class 3B lasers

Class 3B lasers and laser systems:

- Must be posted with the appropriate **warning signs**.
- Must be **operated only by authorized personnel** and in a manner such that the laser beam path is well defined.
- Must have only diffusely reflecting materials in or near the beam path where possible.
- Must have **all windows, doorways and open portals either covered or restricted** so as to reduce the transmitted laser radiation.
- Must have **appropriate personal protective equipment** readily available (i.e., eye protection).

All area or entryway safety controls must be designed to allow rapid exit of laser personnel under emergency conditions.

With Class 4 lasers

Class 4 laser control areas **must incorporate all Class 3B control measures, plus the following:**

- Control area interlocks or alternate controls to **prevent the entry of unprotected personnel** while Class 4 laser radiation is present. *or*
- **Blocking barrier, screen, curtains**, etc. must be used to block, screen, or attenuate the laser radiation levels so that the MPE is not exceeded at the entry point.
- At the entryway there must be a **visible or audible signal** indicating that the laser is energized and operating at Class 4 levels.