Laser Safety Guide

Environmental Health and Safety

1.0 Purpose and Requirements

This guide presents a summary of the basics of laser safety, biological effects, and exposure limits to be used at Cornell University. This guide applies to all laser classes (1 to 4). Some recommendations will enhance laser safety in the laboratory while others are required by the ANSI Z136.1 laser safety standard.

Questions or comments concerning this guide may be sent to David Rynders (dgr63@cornell.edu).

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2.0 Scope

This guide applies to all users of laser and laser equipment. Because of the wide variety of lasers and laser uses that are possible, this guide provides performance based goals rather than prescriptive requirements. Implementation of the goals is left to the principle investigator, supervisor, and the laser safety officer and will be designed to meet the research and safety needs of the particular application.

3.0 Definitions

- LSO
  Laser Safety Officer
- Laser
  Light Amplification by the Stimulated Emission of Radiation
- MPE
  Maximum Permissible Exposure as listed in ANSI Z136.1 standard. The maximum allowed exposure to the eye or skin to laser radiation.
- ANSI Z136.1
  The American National Standards Institute (ANSI) standard *For The Safe Use of Lasers*.
- NHZ
  Nominal Hazard Zone is the space or area where laser radiation levels exceed the MPE. For example, the NHZ could be an

entire room, or a smaller area within a room that is surrounded by barriers to contain the beam.

- Visible light
  Wavelengths between 400 nm and 700 nm.
- Invisible light
  All other wavelengths below 400 nm and above 700 nm.
- Optical Density – OD
  The power of 10 reduction in intensity through the eye protection. For example, an OD of 3 means 1/1000 of the laser intensity passes through eye protection.
- Entryway
  A door, passage, or entrance from a public area, or non-laser use area, leading into the NHZ or laser use area.

4.0 Responsibilities

4.1 Principle Investigator or Supervisor / Manager

The PI or supervisor is responsible for the health and safety of those reporting to him/her. They are also responsible for ensuring that lasers are properly installed and used, laser users have been properly trained, and that their laser installations comply with the goals and requirements of this guide.

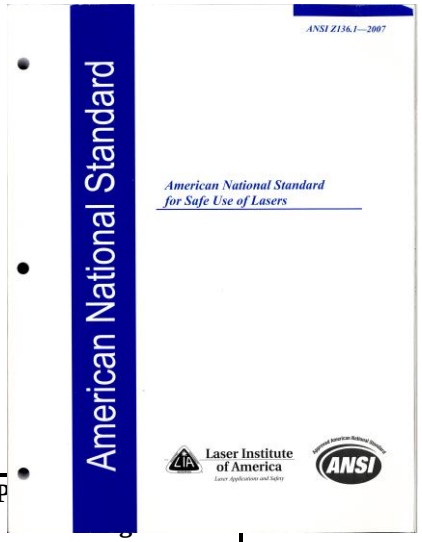
4.2 Laser Users

Each laser user is responsible for the safe operation of his/her laser. This includes being aware of the position and termination of all beams and reflections, using appropriate entryway controls, and using appropriate eye protection.

Laser users shall not bypass or defeat entryway safety features, barriers, or interlocks. Doing so is a serious safety violation and may lead to loss of laser use privileges.

4.3 LSO

The LSO is responsible for assuring that laser hazards are evaluated and appropriate safety measures are implemented by the PI and users. The LSO will assist with laser safety training, the selection of eye protection, and inspecting laser use areas and equipment.



5.0 Regulation and Standards

5.1 ANSI Z136.1

The American National Standards Institute publishes ANSI Z136.1 *For the Safe Use of Lasers* and represents a consensus standard for laser safety. The standard is based on

the goal that the level of safety control matches the hazard present. **Cornell will follow the ANSI standard.**

The Z136.1 document is the main standard but two others that may also be applicable:
Z136.2 *Safe Use of Optical Fiber Communication Systems*
Z136.5 *Use of Laser in Educational Institutions*

5.2 FDA CDRH Federal Regulations

The Center for Devices and Radiological Health (CDRH), which is part of the Food and Drug Administration (FDA) at the federal government level, regulates laser products marketed in the United States. All laser and laser equipment marketed is required to meet the minimum safety requirements found in 21 CFR 1040.10.

The CDRH requirements apply to anyone who builds a laser or laser equipment, or modifies equipment, and provides the equipment to a third party. Lasers or equipment built or modified by a person for their own use is exempt from the CDRH requirements.

Contact the LSO for more information if you will build or modify lasers or laser equipment for someone else.

5.3 NY Dept of Labor Code Rule 50

New York is one of few states with a laser safety regulation. The important parts of CR50 are summarized here:

50.5 – Employers shall not permit an individual to be exposed to laser radiation above maximum permissible levels without the person using personal protective equipment.
50.6 – Every employee shall use protective equipment provided for his or her use.
50.12 – Protective eyewear shall be used by all persons when laser use conditions could lead to an accidental exposure above the maximum permissible exposure limit.

6.0 General Safety Performance Standards

6.1 For All Laser Classes

The purpose of control measures is to reduce the possibility of eye and skin exposure to hazardous levels of laser radiation and associated hazards.

Engineering control measures shall be given primary consideration when developing a laser hazard control program. Figure 1 shows the ANSI requirements for laser hazard controls. Procedural or administrative control measures, as allowed by ANSI, may be utilized when engineering controls are impractical or inappropriate and the PI / supervisor and LSO agree that an equivalent level of protection is obtained (ANSI 4.2).

When multiple class lasers are in use, or will be used, the highest laser class will determine the level of safety to be implemented.

6.2 Temporary Higher Class Laser Use Areas

When an operation creates a temporary high class area (e.g. removing the enclosure of Class 1 laser equipment to access the Class 4 laser inside for maintenance), control measures for the higher class laser will be temporarily implemented. When a temporary area is created, the warning signs posted may need to be changed to reflect the new hazard level. Contact the LSO to discuss temporary laser areas.

6.3 Beam Control

No laser beam, regardless of class, may intentionally leave the NHZ unless approved by the LSO. This includes fiber optic transmission between labs and wall and floor penetrations. Precautions shall be taken to anticipate all possible reflections and prevent them from leaving the NHZ. Proper placement and orientation of the laser and optical path can contribute significantly to meeting this performance standard.

Where possible, use of fiber optics is high recommended. Once the beam is contained in a fiber, the laser hazard is greatly reduced.

6.4 Designing Laser Labs and Use Areas

Laser safety considerations must be included early in the design of new labs or use areas. Section 7 provides safety performance standards, by laser class, to be included in the design, layout, and construction of any laser lab or use area.

Some general considerations include:

- Keep laser use to the rear of rooms whenever possible.

- Keep laser beams and optical paths pointing away from doorways, windows, or the entrance to the NHZ.
- Keep beam paths above or below eye level.
- Use of barriers, shields, or enclosures close to the beam or optical path provides the best protection.

Figure 2 shows the minimum required clearances around equipment in laser labs and use areas.

Figure 3 gives the minimum requirements for hazardous laser gases.

6.5 Training

The level of training shall be appropriate to the level of the laser hazard being used (ANSI 5.5). EH&S provides general laser safety training that is to be supplemented by specific in-lab training by the PI / supervisor or experienced user designated by the PI / supervisor to provide training.

- Class 1 and 2 – training not required
- Class 1M and 2M – application dependent, contact the LSO
- Class 3a and 3R – training not required
- Class 3b and 4 – training is required

Refresher training is required every two years. Attendance at a laser safety class or completing an on-line refresher course will meet this requirement.

6.6 Relocation of Lasers and laser Labs or Use Areas

The new lab or use area must meet the performance standards appropriate for the laser class prior to operating the laser(s).

6.7 Eye Exams

Baseline eye exams are not required for most Class 3b and Class 4 laser use. However, if a potential user has a medical issue (e.g. prior laser eye injury, pre-existing medical condition, medication that enhances photosensitization) that would make them more susceptible to laser radiation, this should be discussed with the Cornell Laser Safety Officer to determine the appropriate course of action. The LSO also reserves the right to recommend a baseline exam in unusual or specialized laser applications.

7.0 Class Specific Laser Safety Performance Standards

7.1 Class 1 Lasers and Laser Equipment

Class 1 lasers and laser equipment represents laser radiation exposures at or below the MPE.

- There are no laser safety requirements for this class.

Note: Class 1 equipment typically has higher class lasers inside. Removing access panels and enclosures may create an NHZ outside the equipment which will require high class control measures.

7.2 Class 1M, 2, 2a, 2M, 3a, and 3R Lasers and Equipment

These lasers represent a minimal hazard. Requirements are:

- Post the appropriate warning sign at the entrance to the laser area. The sign will be CAUTION or DANGER depending on the highest class laser in use. Generally, using a copy of the label attached to the laser will meet this requirement. The LSO can provide signs.
- Windows should be covered with laser opaque material and keep lab doors should be kept closed when lasers are operating. Laser opaque material can be filter material of the appropriate OD.

7.3 Class 3b Lasers and Equipment

Lasers in this class are capable of causing eye and skin (at higher laser powers) injury.

- DANGER signs are required at the entrance to the NHZ. The LSO can provide signs with the proper wording.
- Because of the wide power range for Class 3b, lasers at the upper end of this class may require entryway protection (e.g. barriers or curtains) to meet the requirement of Section 6.3. Contact the LSO to make this determination.
- If the entryway is not protected by alternate means, windows shall be covered with laser opaque material and doors shall be closed when the laser is operating.
- For shared laser and non-laser use spaces, the area shall be arranged so that non-laser users do not have to pass through a laser area to reach their work area.
- The laser work area shall be inspected to ensure all specular reflections are eliminated.
- Eye protection is required during laser and optical

beam path alignment.
- Written alignment procedures are required.

7.4 Class 4 Lasers and Equipment

Class 4 lasers are eye and skin injury hazards, diffuse reflection hazards, and fire hazards.

- DANGER signs are required at the entrance to the NHZ. The LSO can provide signs with the proper wording.
- Class 4 lasers require entryway protection (e.g. barriers or curtains) to meet the requirement of Section 6.3. Figures 4, 5, 6, and 7 provide some examples of acceptable barrier designs.
- Entryway protection shall be designed to prevent a single bounce or reflection from reaching public or non-laser areas.
- Entryway protection shall be designed to allow enough room for people entering to put on eye protection before entering the NHZ or laser use area.
- The entryway protection is required to be in place before the laser is allowed to operate. Class 4 lasers have an electrical interlock connection that may be connected to the entryway protection for this purpose. For example, if a curtain is used around a laser setup, an interlock switch is required on the curtain if the curtain is movable in its track. This ensures that the curtain is fully closed before laser operation is enabled. If the curtain is fixed in its track so it is always in place, then no interlock is required.

  If the laser cannot be shutdown, then the beam must be terminated if the entryway protection is not in place. For example, a shutter or beam block must block the beam until the entryway protection is fully in place.
- When curtains are used as entryway protection and a split is present, the curtain parts must overlap each other by at least 6 inches (15 cm).
- A laser warning light is required at the entrance to the NHZ or laser use area. If possible, an automatic light is strongly recommended so the light is turned on or off when the laser is on or off. The LSO can provide recommendation for suppliers of laser lights.

If the light is manually controlled, the light switch shall be located near the laser controls.

The light shall be located as close to general eye level as possible (e.g. about 60 inches or 152 cm above the floor) to the side of the entryway.

- Depending on the size of the NHZ or laser use area, emergency shut off switches may be required at strategic locations. The LSO will assist in making this determination.
- For shared laser and non-laser use spaces, the area shall be arranged so that non-laser users do not have to pass through a laser area to reach their work area.
- The laser work area shall be inspected to ensure all specular reflections are eliminated.
- Eye protection is required at all times the beam is not fully enclosed or contained.
- Written alignment and operating procedures are required.
- To prevent unauthorized use, entrances to laser labs or areas should be locked when not occupied for extended periods of time.

7.5 Special Class 4 Considerations

Because Class 4 lasers represent a fire hazard, the ignition potential of any materials in the NHZ that could be exposed to the beam must be considered.

For UV lasers, ablative photodecomposition of materials exposed to the beam may be a concern. These products are of an unknown composition and may represent a toxic or carcinogenic exposure hazard. Local ventilation may be required and the LSO will assist with this determination.

8.0 Personal Protection Standards

8.1 Eye Protection

Eye protection is most important for Class 3b and Class 4 lasers. Eye protection with low OD may be desired for the lower classes due to the extreme brightness of laser beams in general. The LSO will assist with eyewear selection.

Note that eye protection is generally not designed to withstand the direct hit of a high powered Class 4 beam. Pulsed lasers can have extremely high peak powers and cause instant eyewear failure. Users must take all possible

precautions to avoid and prevent direct beam exposures.

8.2 Skin Protection

For UV lasers, skin exposure is a concern for sun burn like effects and an increased risk of skin cancer. When UV scatter cannot be reduced by shielding, other forms of skin protection must be used. Chemical face shields can block all scattered mid to far UV while lab coats and gloves can reduce exposure to the rest of the body.

9.0 Laser Use Outdoors

Because of Federal Aviation Administration (FAA) and New York State regulations, laser use outdoor is not permitted at any time unless approved by the LSO. The LSO will coordinate notification to the FAA and NY to obtain the required approvals.

Note: this does not include the use of lasers by construction, maintenance, surveying, or shops personnel who are covered under OSHA.

10.0 Use of Lasers by Construction, Shops and Surveying Personnel

Use of lasers is regulated by OSHA and requires laser safety training. The LSO will provide this training upon request. Contact the LSO for more information.

11.0 Related Hazards

11.1 Electrical

The greatest cause of injury with lasers has been related to electrical accidents. Nearly all lasers that use wall supplied AC power have high voltage inside. Battery powered lasers do not generally have high voltage concerns but this is not always the case. Follow basic electrical safety practices and electrical safety training is provided by EH&S. See CULearn for available safety classes.

11.2 Chemical

Dye lasers use fluorescent organic dyes to obtain tunable beams. The dyes vary widely in toxicity and are sometimes dissolved in hazardous solvents. Be sure to review the Material Safety Data Sheet (MSDS) for the dye and solvent before handling these chemicals. In some cases use in a fume hood or other ventilation may be required.

F_2 and HCl gas safety is discussed in Figure 3.

Some optical components are made of hazardous materials. Some examples are calcium telluride, zinc telluride, cadmium oxide, and beryllium. If irradiance limits are exceeded these may decompose.

11.3 Explosion

If optical components are not kept clean or if irradiance limits are exceeded, these may explode creating a flying object hazard. Be sure to inspect optics regularly and replace any components that are suspect or visibly damaged.

12.0 Transfer or Disposal of Lasers

12.1 **Transfer**

Because some lasers utilize hazardous materials, transfer of lasers to others outside of Cornell may require the laser be decontaminated prior to shipment. Contact the LSO for more information.

12.2 Disposal

New York State requires that all lasers for disposal must be made inoperable. Acceptable methods include:

- Cutting off power cords
- Breaking laser tubes (using proper safety and exhaust precautions)
- Disconnecting and separating power supplies from laser head or modules.

All dye, chemicals, and gases shall be purged and/or rinsed to remove all traces of hazardous materials. Waste is to be properly packaged and disposed of. Contact EH&S for assistance.

13.0 Accidents and Exposures

If an actual immediate eye injury has occurred, follow these steps:

- Call 911 or have someone else call Cornell Police at 911
- Report the injury and request medical assistance
- Request that EH&S Radiation Safety be paged
- Notify your PI or supervisor

For a delayed injury that appears later in time:

- Go to the Gannett Health Center if you can or to the nearest hospital emergency room
- When you or some else is able, call Cornell Police at 607-255-1111 and request that EH&S Radiation Safety be paged

- Notify your PI or supervisor

For avoided accidents or near misses:

- Notify your PI or supervisor
- Contact EH&S Radiation Safety at 607-255-8200

Figure 1 – ANSI Z136.1 Table 10 Control Measure for the Seven Laser Classes

Table 10. Control Measures for the Seven Laser Classes

Engineering Control Measures	Classification						
	1	1M	2	2M	3R	3B	4
Protective Housing (4.3.1)	X	X	X	X	X	X	X
Without Protective Housing (4.3.1.1)	LSO shall establish Alternative Controls						
Interlocks on Removable Protective Housings (4.3.2)	∇	∇	∇	∇	∇	X	X
Service Access Panel (4.3.3)	∇	∇	∇	∇	∇	X	X
Key Control (4.3.4)	—	—	—	—	—	•	X
Viewing Windows, Display Screens and Collecting Optics(4.3.5.1)	Assure viewing limited < MPE						
Collecting Optics (4.3.5.2)							
Fully Open Beam Path (4.3.6.1)	—	—	—	—	—	X NHZ	X NHZ
Limited Open Beam Path (4.3.6.2)	—	—	—	—	—	X NHZ	X NHZ
Enclosed Beam Path (4.3.6.3)	None is required if 4.3.1 and 4.3.2 fulfilled						
Remote Interlock Connector (4.3.7)	—	—	—	—	—	•	X
Beam Stop or Attenuator (4.3.8)	—	—	—	—	—	•	X
Activation Warning Systems (4.3.9.4)	—	—	—	—	—	•	X
Indoor Laser Controlled Area (4.3.10)	—	*	—	*	—	X NHZ	X NHZ
Class 3B Indoor Laser Controlled Area (4.3.10.1)	—	—	—	—	—	X	—
Class 4 Laser Controlled Area (4.3.10.2)	—	—	—	—	—	—	X
Outdoor Control Measures (4.3.11)	X	* NHZ	X NHZ	* NHZ	X NHZ	X NHZ	X NHZ
Laser in Navigable Airspace (4.3.11.2)	X	* NHZ	X NHZ	* NHZ	X NHZ	X NHZ	X NHZ
Temporary Laser Controlled Area (4.3.12)	∇ MPE	∇ MPE	∇ MPE	∇ MPE	∇ MPE	—	—
Controlled Operation (4.3.13)	—	—	—	—	—	—	•
Equipment Labels (4.3.14 and 4.7)	X	X	X	X	X	X	X
Laser Area Warning Signs and Activation Warnings (4.3.9)	—	—	—	—	•	X NHZ	X NHZ

LEGEND:
- X — Shall
- • — Should
- — — No requirement
- ∇ — Shall if enclosed Class 3B or Class 4
- MPE — Shall if MPE is exceeded
- NHZ — Nominal Hazard Zone analysis required
- * — May apply with use of optical aids

Figure 1 Continued – ANSI Z136.1 Table 10 Control Measure for the Seven Laser Classes

Table 10. Control Measures for the Seven Laser Classes (cont.)

Administrative and Procedural Control Measures	Classification						
	1	1M	2	2M	3R	3B	4
Standard Operating Procedures (4.4.1)	—	—	—	—	—	•	X
Output Emission Limitations (4.4.2)	—	—	—	—	LSO Determination		
Education and Training (4.4.3)	—	•	•	•	•	X	X
Authorized Personnel (4.4.4)	—	•	—	•	—	X	X
Alignment Procedures (4.4.5)	∇	∇	∇	∇	∇	X	X
Protective Equipment (4.6)	—	•	—	•	—	•	X
Spectators (4.4.6)	—	•	—	•	—	•	X
Service Personnel (4.4.7)	∇	∇	∇	∇	∇	X	X
Demonstration with General Public (4.5.1)	—	•	X	•	X	X	X
Laser Optical Fiber Transmission Systems (4.5.2)	MPE	MPE	MPE	MPE	MPE	X	X
Laser Robotic Installations (4.5.3)	—	—	—	—	—	X NHZ	X NHZ
Protective Eyewear (4.6.2)	—	—	—	—	—	•	X
Window Protection (4.6.3)	—	—	—	—	—	X	X NHZ
Protective Barriers and Curtains (4.6.4)	—	—	—	—	—	•	•
Skin Protection (4.6.6)	—	—	—	—	—	X	X NHZ
Other Protective Equipment (4.6.7)	Use may be required						
Warning Signs and Labels (4.7) (Design Requirements)	—	—	•	•	•	X NHZ	X NHZ
Service Personnel (4.4.7)	LSO Determination						
Laser System Modifications (4.1.2)	LSO Determination						

LEGEND:
- X — Shall
- • — Should
- — — No requirement
- ∇ — Shall if enclosed Class 3B or Class 4
- MPE — Shall if MPE is exceeded
- NHZ — Nominal Hazard Zone analysis required
- • — May apply with use of optical aids

Figure 2 – Minimum Clearances for Laser Labs

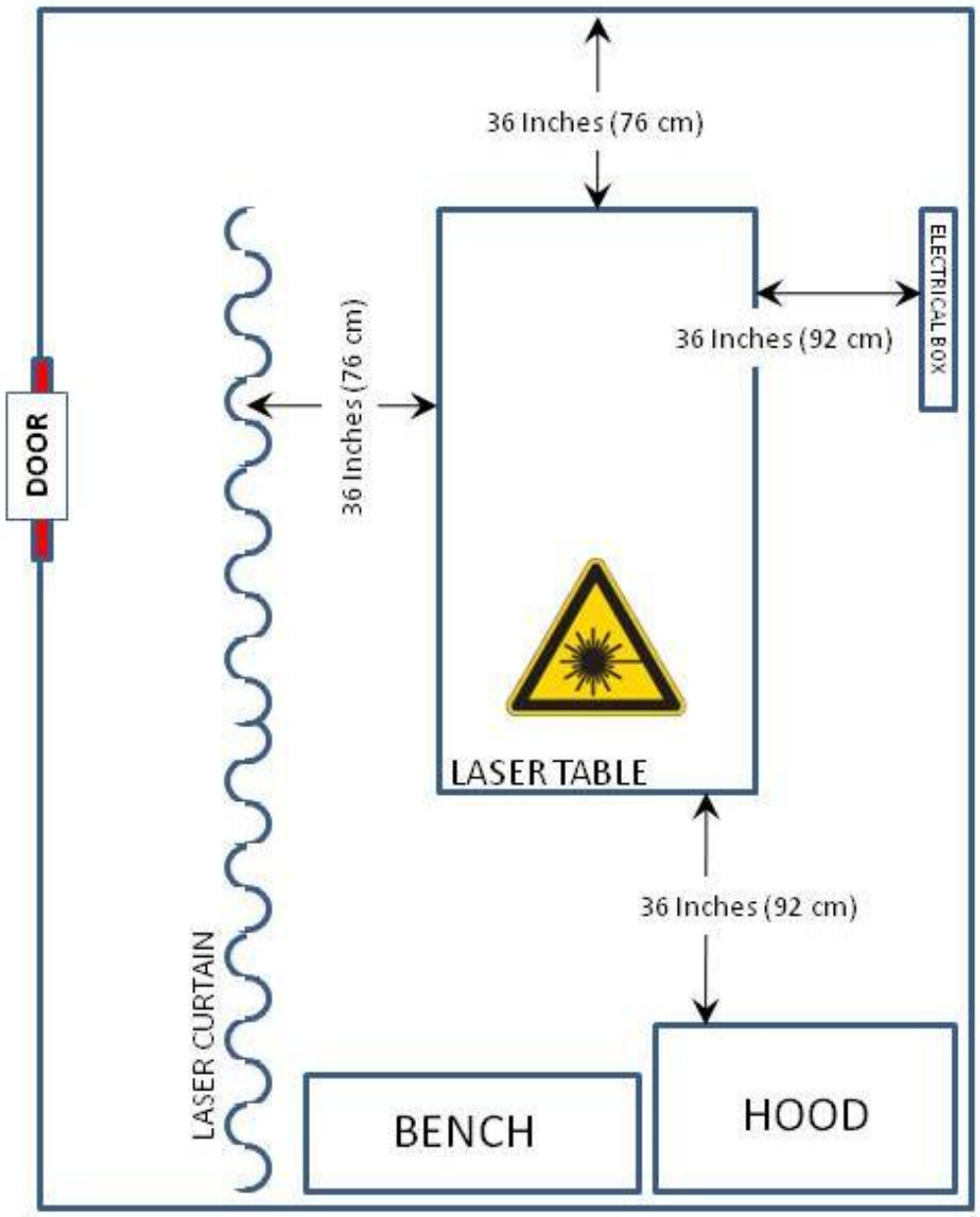


Figure 3 – Minimum Requirements for Hazardous Laser Gases

Fluorine and Chlorine Mixtures

- Use the smallest sized cylinder possible. Recommended shelf life is one year.
- All gas cylinders must be properly secured to prevent tipping over or falling. This includes small cylinders in hoods as well as larger cylinders.
- Exhausted gas cabinet for larger cylinders or fume hood for smaller cylinders.
- Vent used laser gases to the exhaust system.
- Purge all gas lines and connections with nitrogen prior to opening gas lines.
- Stainless steel gas tubing, connectors and regulators are recommended (for gas safety and purity). Copper tubing can be used for F_2 gas.
- Use a flow restricting orifice to limit releases.
- Use the two person rule when working with gas and gas lines.
- Keep the number of connections to a minimum – every connection is a potential leak.
- Use personal protective equipment – eye protection and neoprene gloves.
- Consider using an on-demand F_2 generator system rather than gas cylinders.
- Anyone handling or using toxic gases must have training (hands-on as well as EHS gas safety – see CULearn for EH&S safety classes).

Figure 4 – Example of High Power Class 3b or Class 4 Entryway Protection

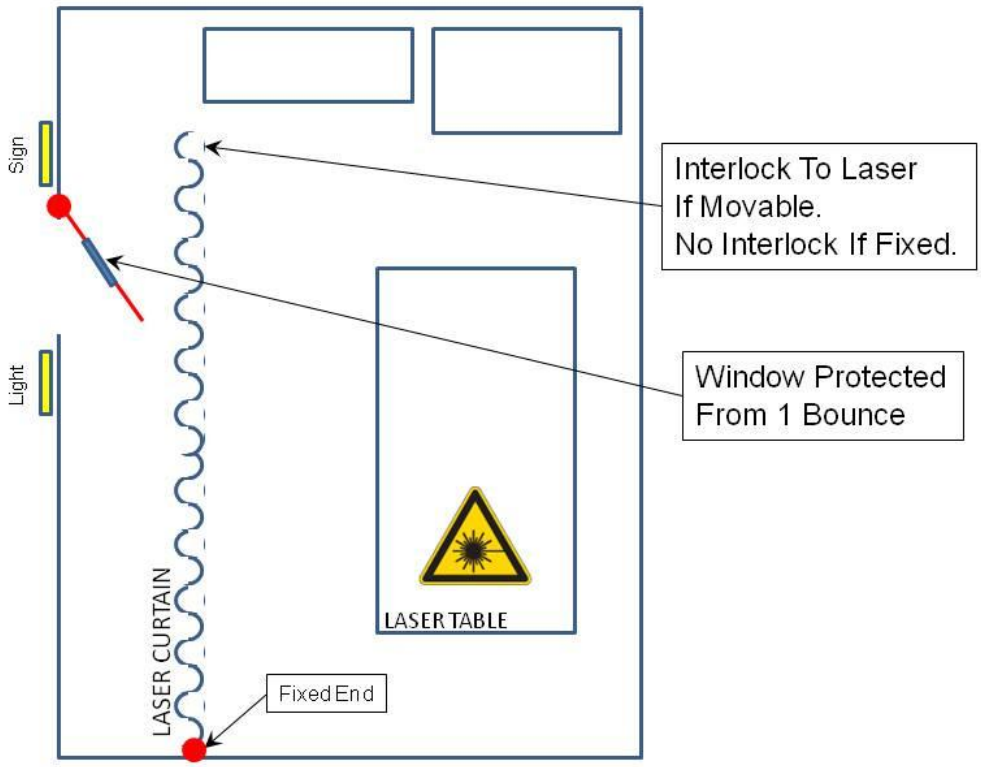


Figure 5 – Example of High Power Class 3b or Class 4 Entryway Protection

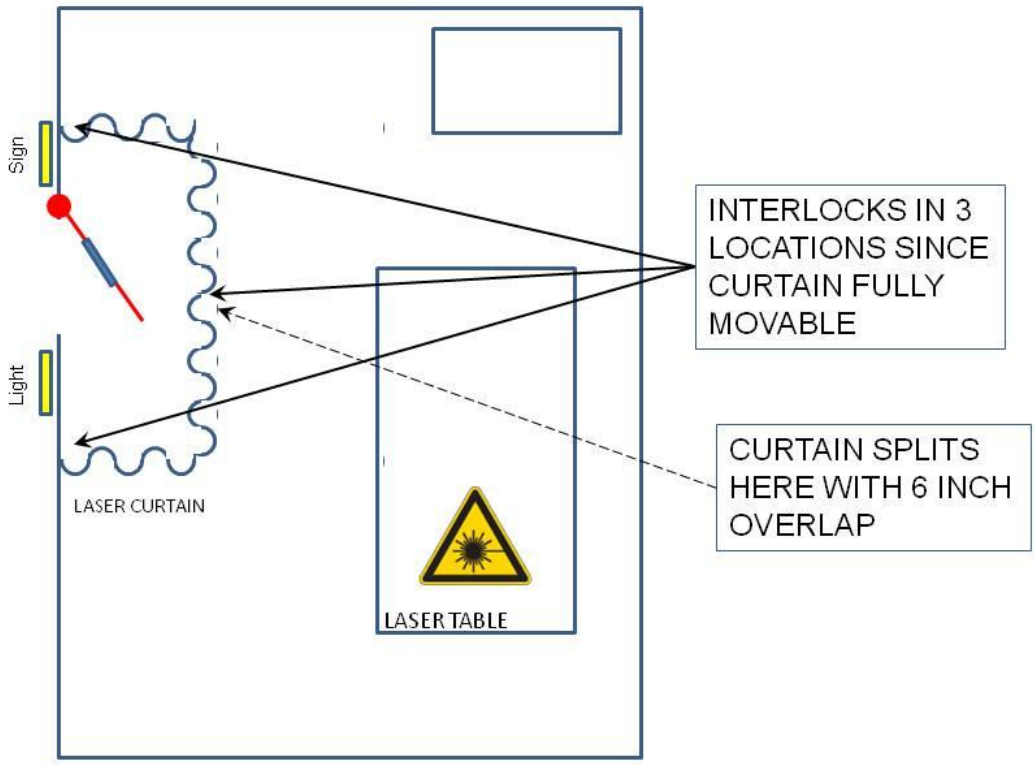


Figure 6 – Example of High Power Class 3b or Class 4 Entryway Protection

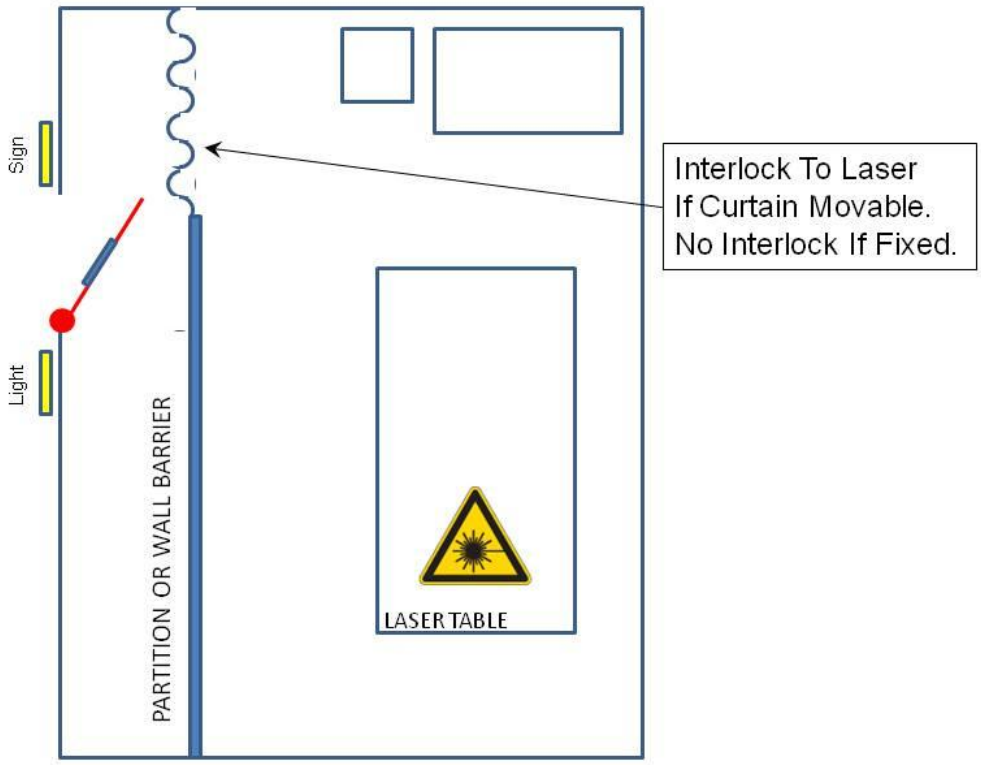


Figure 7 – Example of High Power Class 3b or Class 4 Entryway Protection