ENVIRONMENTAL HEALTH AND SAFETY
University of Nebraska-Lincoln

Safe Operating Procedure
(Created 7/24)

LASER SAFETY CONTROL MEASURES

Purpose

This Safe Operating Procedure (SOP) summarizes the control measures requirements to possess and operate Class 3B and Class 4 lasers and laser systems used for research and development applications. Control measures are implemented to eliminate or greatly reduce the possibility of eye or skin exposure to hazardous levels of laser radiation and other ancillary hazards associated with the use of laser and laser systems. The environment where a laser will be used, and application of the laser are also factors to consider when determining the appropriate control measures to be applied.

The content of this SOP is based on the ANSI Z136.1-2022, Safe Use of Lasers standard, ANSI Z136.8-2021, Safe Use of Lasers in Research, Development, or Testing standard, and NFPA 115, Standard for Laser Fire Protection standard.

When selecting appropriate control measures, follow the hierarchy of controls which favors engineering controls, followed by administrative controls, and finally personal protective equipment (PPE). If engineering controls alone are inadequate or infeasible, use an effective combination of engineering, administrative, and PPE controls to provide adequate protection. Control measures for the use or application of any Class 3B or Class 4 lasers and laser systems must be approved by the Laser Safety Officer and Laser Safety Committee.

Definitions

Engineering Control Measures means measures designated or incorporated into the laser or laser system for ensuring safe operating and minimizing the risk of exposure to laser radiation such as interlocks, shutters, protective barriers, area warning devices, entry controls, and emergency stops.

Administrative Control Measures means measures incorporating policies, procedures, and practices such as standard operating procedures, alignment procedures, education and training, authorized personnel, and warning signs and labels to mitigate the potential hazards associated with laser use.

Personal Protective Equipment (PPE) means personal safety protective devices used to mitigate hazards associated with laser use, for example, laser protective eyewear, protective clothing, and gloves.

Laser Controlled Area (LCA) means a laser use area where the occupancy and activity of those within is controlled and supervised. That area may be defined by walls, barriers, or other means. Potentially hazardous beam exposure is possible within the LCA.

Maximum Permissible Exposure (MPE) means the level of laser radiation to which an unprotected person may be exposed without adverse biological changes in the eye or skin.

Engineering Controls

The engineering control measures required for Class 3B and 4 lasers and laser systems are summarized below. User-developed or user-modified laser products must have these controls reviewed and approved by the Laser Safety Officer and Laser Safety Committee.

Engineering Controls	Class 3B	Class 4
Protective Housing, Service Access Panels, and Equipment Labeling	✓	✓
Protective Barriers and Curtains	✓	✓
Beam Paths	✓	✓
Viewing Windows, Diffuse Display Screens, and Collecting Optics	✓	✓
Key Control	+	✓
Remote Interlock Connector	+	✓
Beam Stop or Attenuator	+	✓
Laser Activation Warning System	+	✓
Emission Delay		✓
Remote Firing and Monitoring		✓
Emergency Stop Button		✓
Entryway Controls		✓

✓ Required
+ Recommended

Protective Housing, Service Access Panels, and Equipment Labeling

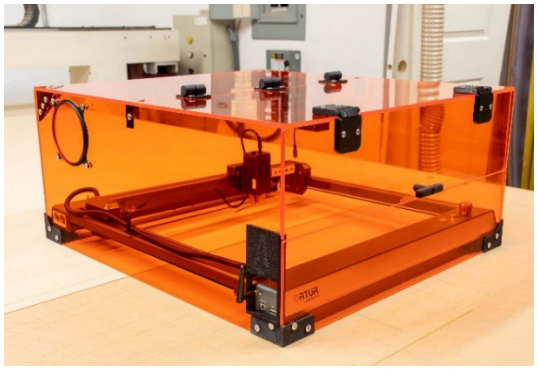
Class 3B and Class 4 lasers must be housed in robust, durable enclosures specifically designed to contain laser radiation. These housings must be constructed of materials that can withstand exposure to laser beams without transmitting or reflecting beams or failing. The protective housing for lasers and laser systems must be fully assembled during operation.

Portions of the protective housing that are only intended to be removed from any laser or laser system that permit direct access to laser radiation must have an interlock or require a special tool for removal. The service access panels limit user exposure to laser radiation or other associated hazards. The service panel must be appropriately labeled to indicate the hazard present to the user.

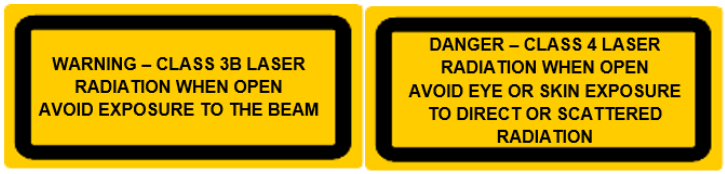
A label that indicates the relative hazard of laser radiation contained within the housing shall be placed on all removable protective housings that have no safety interlock that can be removed or displaced during operation, maintenance, or service, and thereby, allow access to laser radiation greater than the applicable MPE.

In many cases, the classification of a laser or laser system is dependent on the protective housing limiting the accessible radiation. User manufactured or aftermarket protective housings and enclosures must adhere to the same criteria and are subject to Laser Safety Officer (LSO) and Laser Safety Committee (LSC) review and approval.

Protective housing limits laser radiation access through beam aperture.



Enclosed laser system contains laser radiation during operation within protective housing.



Sample Service Panel Laser Hazard Signs Requiring a Special Tool

Laser Access Panel

Protective Barriers and Curtains

Physical barriers and curtains may be used to prevent direct line-of-sight exposure to laser beams. Barriers can be constructed from materials that block or attenuate laser radiation, while curtains may be made from opaque laser-safe fabrics. The design and installation of laser barriers and curtains must account for the likely beam paths within the area as well as any potential reflections. When used to designate a Laser Controlled Area (LCA), the LCA signage must be featured prominently on the barrier's exterior.

Sample Laser Barriers

Sample Laser Curtains

These barriers and curtains are required to sufficiently absorb or attenuate the laser radiation emitted within an LCA to be considered an adequate control measure. This requires the user to verify that the

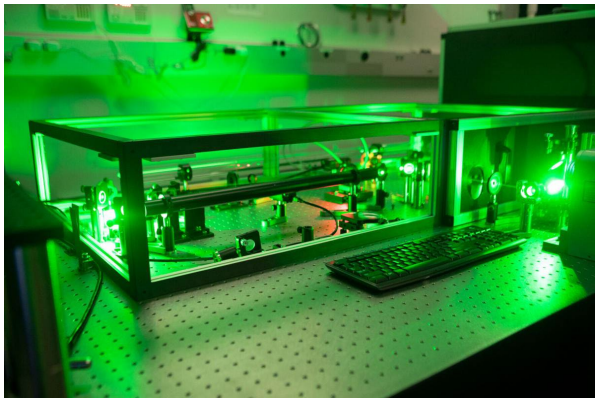
barrier or curtain is rated for the intensity of the laser radiation emitted. Manufacturers will typically provide documentation on the ratings for barriers and curtains commercially available. Information regarding a barrier or curtains rating may be found on barrier or curtains as labels or tags.

Sample Laser Barrier/Curtain Rating Labels

Beam Paths

Beam paths can be fully open, limited open, and enclosed. In all beam path cases, the LSO will conduct a hazard analysis to specify the control measures needed. In applications of lasers or laser systems where the entire beam path is enclosed and the enclosure limits exposure to laser radiation to levels at or below the applicable MPE, the laser may be reclassified to a Class 1 laser upon approval of the LSO and LSC. This reclassification is not considered during alignment, servicing, or repairs to the laser.

When the configuration of the laser or laser system is temporarily adjusted resulting in an exposed beam path, such as during maintenance or alignment procedures, control measures appropriate for the exposed laser radiation must be implemented, even if on a temporary basis. The use of a beam path containment system may be appropriate to limit exposure to a laser beam.

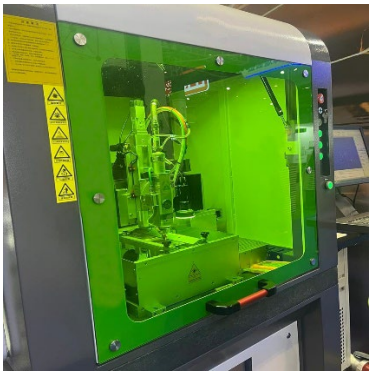


Beam Tube Laser Containment System

Different beam paths at UNL

Viewing Windows, Diffuse Display Screens, or Collecting Optics

All viewing windows and diffuse, reflective or transmitted, display screens included as an integral part of a laser or laser system shall incorporate a suitable means, such as interlocks, filters, or attenuators, to maintain the laser radiation at the viewing position at or below the applicable MPE as determined by the LSO.



Viewing window protection

Collecting optic

Key Control

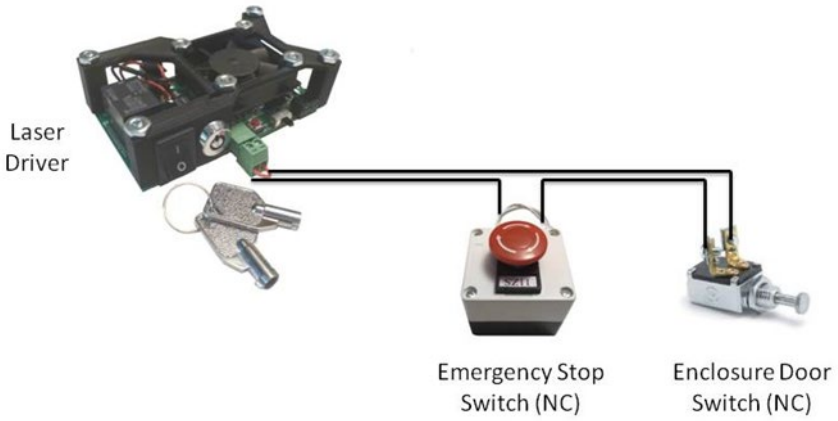
This switch must terminate the beam and shut down the system. This can be operated by a key or by coded access via a computer system. Restrict the key or code that enables operation of a class 3B or class 4 laser or laser system to an appropriate supervisor or authorized laser operator. Disable the switch when the laser is not in use or authorized personnel is not present and in control.

Laser Key Control Examples

Remote Interlock Connector

A remote interlock connector is found on a laser, laser system, or its control module required by 21 CFR 1040.10. The connector can be used to interface with other Laser Controlled Area (LCA) controls to limit or reduce laser radiation exposure if an unsafe condition arises.

Remote Interlock Connector on Laser



Sample Remote Interlock Connector Arrangement

Beam Stops and Attenuators

Beam stops are devices designed to intercept and absorb laser radiation, preventing it from escaping the controlled area. Beam stops are typically made from materials that can safely dissipate the energy of the laser beam without generating hazardous reflections or scattering.

Sample Beam Stops/Dumps

Like beam stops, attenuators are devices designed to intercept and decrease the flux density or power per unit area of a beam through absorption and scattering of the beam. These can be used in conjunction with other optics to manipulate the properties of the beam to suit the user's needs.

Sample Beam Attenuator

The beam stop or attenuator must be capable of preventing laser radiation more than the appropriate MPE. A user manufactured beam stop, or dump may be used, provided it has the required properties to intercept and absorb the corresponding laser radiation.

Laser Activation Warning System

An area warning device, such as a visible or audible alarm, may be installed to alert personnel when a laser is in operation. The purpose of the area warning device is to ensure that persons who are about to enter the Laser Controlled Area (LCA) are aware that a laser is emitting or is about to begin emitting accessible laser radiation within the area. Special care should be taken to ensure that emission warning is not rendered ineffective if it would not be visible through laser protective eyewear or if an auditory warning is used that an alternative means is implemented where hearing impaired persons may be present.

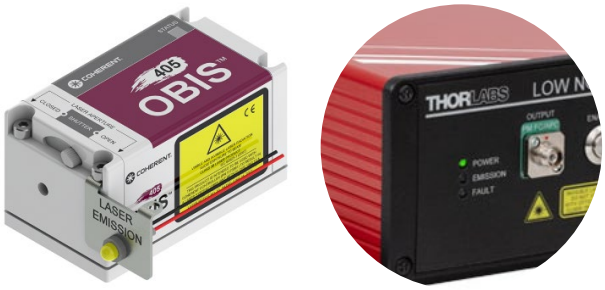
Examples include an illuminated single lamp or a laser warning sign that is lighted or flashes when the laser is operating. This light or lighted sign can be electrically interfaced and controlled by the laser power supply so that the light is on or flashing only when the laser is operating or must alternatively be engaged by the operator as part of the written operating procedures.

Sample Emission Warning Sign/Light

Sample Emission Warning Status Panels

Emission Delay

Emission delay provides sufficient time prior to emission of laser radiation to allow appropriate action to be taken by operators to avoid exposure to the laser radiation. Within the Laser Controlled Area (LCA), an audible or visible laser radiation emission warning device, or emission indicator, must be used during activation or startup. The purpose of this radiation emission warning is to ensure that persons within the LCA are aware that a laser is emitting or is about to begin emitting accessible laser radiation. The most common laser radiation emission warning device is a single, red light located on the laser or its control panel.



Sample Emission Warning Lights on Lasers

Sample Emission Warning Light on Control Panels

Remote Firing and Viewing

Remote firing and monitoring console allows the laser to be operated from a remote location.

Remote viewing and firing from Diocles Control Room at UNL

Emergency Stop Button

For emergency conditions, there shall be a clearly marked “Emergency Stop”, or other appropriate marked device, such as a remote-controlled connector or equivalent device, suitable for the intended purpose of deactivating the laser or reducing the output to levels at or below the applicable MPE.

Laser outfitted with emergency stop button.

Sample Emergency Stop on Control Panel

Entryway Controls

Entryway controls are mechanisms designed to enforce safety protocols before allowing individuals to enter the Laser Controlled Area (LCA). These controls may include interlocked doors or gates that require authorization before granting access to the laser workspace. Entryways must incorporate one of the following controls: Nondefeatable (nonoverride), Defeatable, or Procedural Safety Controls. All Class 4 area or entryway safety controls shall be designed to always allow unobstructed egress by laser personnel and admittance to the LCA under emergency conditions.

Nondefeatable means "cannot be defeated". The nondefeatable safety circuit is the safest, simplest, and least expensive type of engineering control. The interlock connection of a Class 4 laser (or shutter at the output of the laser) is connected to a safety circuit that extends to one or more limit switches at the entryway door(s). Open the door and the laser turns off or the shutter closes. The non-defeatable entryway control is the ***preferred*** method of protection. It has the advantage of not requiring complex barriers or expensive laser curtains at the doorway since the door is an interlocked barrier.

A defeatable safety control is a type of room interlock that allows authorized trained personnel to momentarily defeat (bypass) the interlock limit switches at a room entryway to enter and exit the room without interrupting laser operation. To be safe and effective, it is crucial that the level of laser radiation does not exceed the MPE at the entry point. This often requires the installation of barriers or laser curtains at the interior of the entryway. It is important to note that the ANSI Z136.1 standard recommends the defeatable interlock only if nondefeatable interlocks limit the intended use of the laser or laser system.

The procedural method is only to be used where the non-defeatable and defeatable interlocks are not feasible or are inappropriate.

Example of a Safety Interlock System

Administrative Controls

Administrative and procedural controls are methods or instructions that specify rules, or work practices, or both, which implement or supplement engineering controls. Necessary administrative and procedural controls for 3B and Class 4 laser and laser systems include, but are not limited to:

Standard Operating Procedures

Written standard operating procedures (SOP) are required for Class 3B and Class 4 lasers and laser systems. Copies of these procedures must be readily accessible to operators and service personnel. Written SOPs must include procedures for operation, maintenance, and other relevant safety considerations. A template form is available through EHS.

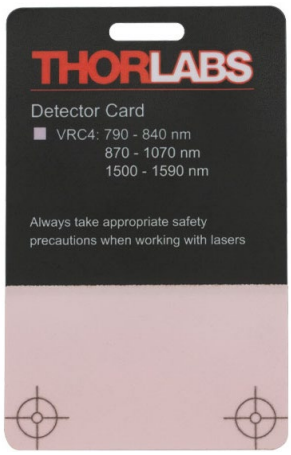
Education and Training

All persons working with Class 3B and Class 4 lasers must receive adequate training commensurate with assigned tasks/duties. EHS provides web-based Laser Safety training. EHS Laser Safety training must be supplemented with laser-specific hands-on training administered by the Authorized User. A hands-on training form is included in the web-based training module and is available through EHS.

EHS also provides an annual laser safety refresher. This fresher training is required annually to reinforce safety knowledge, skills, and lessons learned from the campus community. It is the responsibility of the Authorized User to ensure that all laser users have completed initial and annual refresher training in laser safety.

Alignment Procedures

Alignment procedures detail the steps required to properly align Class 3B and Class 4 lasers, ensuring that the laser beam is directed accurately and safely. These procedures typically include precautions to prevent accidental exposure to laser radiation during alignment activities and may specify use of alignment aids.



Sample Laser Viewing Card

IR Laser Viewer

Temporary Laser Controlled Area (LCA

In situations where laser operations need to be conducted outside of a designated Laser Controlled Areas (LCA), a temporary LCA may be established to ensure proper safety measures are in place. A temporary LCA uses barriers, signage, and access controls to minimize risk of laser-related incidents and requires notification to and approval from the Laser Safety Officer.

Personal Protective Equipment (PPE)

PPE must be used when enclosure of the beam or other control measures do not prevent access to direct or reflected beams at levels above the MPE. PPE consists of laser safety eyewear and clothing that covers exposed skin (e.g., lab coats, long-sleeved shirt, gloves, etc.).

Eye Protection

Laser safety eyewear is crucial for protecting the eyes from direct or reflected laser beams. Laser safety eyewear must provide sufficient optical density (OD) to attenuate the laser radiation to safe levels. Laser safety eyewear must be properly fitted and worn at all times when working with or near Class 3B and Class 4 lasers. Periodic cleaning and inspection by users should be completed

annually. Inspect eyewear before each use and discard if damaged or the fit has become compromised.

Proper eyewear selection requires consideration of the wavelengths, max output energy/power of the laser, and max beam radiant exposure/beam irradiance. Consult the manufacturer regarding specific application and review any provided guidance or documentation. There may be instances where a laser emits multiple wavelengths; in such cases, the eyewear must offer adequate protection for all emitted wavelengths during operation. Laser safety eyewear must be clearly labeled with the ODs and wavelengths for which protection is afforded.

Laser Safety Glasses

OD Markings on Laser Safety Eyewear for Different Emitted Wavelengths

Skin Protection

Skin protection may involve wearing specialized laser-resistant gloves, arm sleeves, or other protective clothing designed to block or attenuate laser radiation. Selection of skin protection depends on factors such as the laser wavelength, output power, and potential exposure areas. Flame retardant materials should be selected for class 4 lasers.

Photochemical injury from exposure to UV radiation emitted from lasers operating in this wavelength range may be possible. When exposure to UV radiation may exceed the skin MPE, tightly woven garments that cover the arms and hands are appropriate. UV- protective face shields are also recommended in these conditions.

UV Laser Safety Clothing