LASER SAFETY MANUAL

UNIVERSITY OF CALIFORNIA SANTA BARBARA

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DEFINTIONS

American National Standards Institute (ANSI) - The technical body which releases the Z136.1 Standard for the Safe Use of Lasers and Z136.8 Standard for Safe Use of Lasers in Research, Development, or Testing published by the Laser Institute of America.

Average Power - The average power of a pulsed laser is the product of the energy per pulse (J/pulse) and the pulse repetition frequency (Hz or pulses/sec). The average power is expressed in Watts (J/sec).

Aversion Response – Closure of the eyelid, eye movement, pupillary construction, or movement of the head to avoid an exposure to noxious or bright light stimulant. The aversion response to an exposure from a bright, visible, laser source is assumed to limit the exposure of a specific retinal area to 0.25 s or less.

Blink Reflex - The blink reflex is the involuntary closure of the eyes as the result of stimulation by an external event such as an irritation of the cornea or conjunctiva, a bright flash, the rapid approach of an object, an auditory stimulus or with facial movements. The ocular aversion response for a bright flash of light is assumed to limit the exposure of a specific retinal area to 0.25 s or less.

Coherent Radiation - Radiation whose waves are in-phase. Laser radiation is coherent and therefore very intense.

Continuous Wave (CW) - A term describing a laser that produces a continuous laser beam while it is operating (verses a pulsed laser beam).

Diffuse Reflection - When an incident radiation beam is scattered in many directions, reducing its intensity. A diffusely reflecting surface will have irregularities larger than the wavelength of the incident radiation beam.

Embedded Laser – An enclosed laser that has a higher classification than the laser system in which it is incorporated, where the system's lower classification is appropriate due to the engineering features limiting accessible emission.

Incoherent Radiation - Radiation whose waves are not in-phase.

Intrabeam Viewing - The viewing condition whereby the eye is exposed to all or part of a laser beam.

Irradiance - The power being delivered over the area of the laser beam. Also called power density, irradiance applies to CW lasers and is expressed in W/cm2.

Laser – Light Amplification by Stimulated Emission of Radiation. A monochromatic, coherent beam of radiation not normally believed to exist in nature.

Laser Controlled Area (LCA) – An area where the occupancy and activity of those within is subject to control and supervision for the purpose of protection from laser radiation.

Laser User - Any person who uses a laser for any purpose on the UC Santa Barbara campus or off-campus property.

Laser Safety Manual - A document defining the UC Santa Barbara Laser Safety Program available on the EH&S website.

Laser Safety Officer (LSO) - A member of the EH&S staff, the laser safety officer (LSO) is responsible for implementation of the Laser Safety Program.

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

Nominal Hazard Zone (NHZ) – The space within which the level of the direct, reflected, or scattered radiation may exceed the applicable MPE. Exposure levels beyond the boundary of the NHZ are below the appropriate MPE.

Optical Density (OD) - Also called transmission density, the optical density is the base ten logarithm of the reciprocal of the transmittance (an OD of 2 = 1% transmittance).

Peak Power - The highest instantaneous power level in a pulse. The peak power is a function of the pulse duration. The shorter the pulse, the greater the peak power.

Radiant Exposure - The energy being delivered over the area of the laser beam. Also called energy density, radiant exposure applies to pulsed lasers and is expressed in J/cm2.

Retinal Hazard Region – Optical radiation with wavelengths between 0.4 and 1.4 µm, where the principal hazard is usually to the retina.

Safety Data Sheet (SDS) - A document, required by law, which is supplied by the manufacturer of a chemical. The SDS details the hazards and protective practices required for protection from those hazards, as well as other information.

Specular Reflection - Results when an incident radiation beam is reflected off a surface whose irregularities are smaller than the radiation wavelength. Specular reflections generally retain most of the power present in the incident beam. Exposure to specular reflections of laser beams is similar to intrabeam exposure.

Standard Operating Procedure (SOP) – Formal written description of the safety and administrative procedures to be followed in performing a specific task. For lasers, SOPs are required for all active Class 3B and 4 lasers.

These procedures must include all safety precautions (beam blocks, eyewear, hands-on training, etc.) to be followed.

Ultraviolet (UV) Radiation - Invisible radiation with a wavelength between 10 nm and 400 nm. The near ultraviolet (UV-A) is the 315 to 400 nm band, the mid ultraviolet (UV-B) is the 280 to 315 nm band, the far ultraviolet (UV-C) is the 100 nm to 280 nm band, and the extreme ultraviolet is the 10 to 100 nm band. Note: Wavelengths below 200 nm are absorbed in the atmosphere and are known as the vacuum ultraviolet.

Visible Light - Radiation that can be detected by the human eye. These wavelengths are between 400 and 780 nm.

INTRODUCTION

The University of California Santa Barbara's Laser Safety Program aims to ensure a safe environment for the use of lasers by staff, researchers, students, and visitors. This manual outlines UC Santa Barbara's policies and guidelines on laser safety and serves as a reference for those using lasers.

REGULATORY REQUIREMENTS

The regulation of laser hazards is governed by the California Code of Regulations (CCR), Title 8, Subchapter 7 General Industry Safety Orders, specifically Section 3203 (Injury and Illness Prevention Program). This section mandates that employers must establish systems to ensure employees adhere to safe and healthy work practices. The enforcement of these regulations is carried out by the California Occupational Safety and Health Administration (CAL-OSHA). Currently, CAL-OSHA does not have specific laser safety regulations but trains its inspectors using the ANSI Z136.1 Standard for the Safe Use of Lasers as the benchmark for safe practices.

The UC Santa Barbara Laser Safety Program adopts the ANSI Z136.1 "Standard for the Safe Use of Lasers" and Z136.8 "Standard for Safe Use of Lasers in Research, Development, or Testing." For lasers used in medical settings, the standards are based on ANSI Z136.3 "Standard for the Safe Use of Lasers in Health Care Facilities." Copies of these standards are available at Environmental Health & Safety (EH&S)

APPLICABILITY / SCOPE

The UC Santa Barbara Laser Safety Program encompasses Class 3B and Class 4 lasers and laser systems located on the main campus and at UCSB-managed off-site facilities. This program applies to all individuals, including faculty, staff, students, and visitors, who operate or are in close proximity to Class 3B or Class 4 lasers.

ROLES / RESPONSIBILITIES

LASER SAFETY OFFICER

The Laser Safety Officer (LSO) is tasked with the development, implementation, and ensuring compliance of the Laser Safety Program. Their responsibilities include:

- Providing or prescribing laser safety training
- Reviewing and approving Standard Operating Procedures (SOPs) for lasers
- Conducting hazard evaluations in areas where lasers are used
- Confirming laser classifications
- Determining necessary control measures
- Performing and documenting audits, surveys, and inspections
- Recommending and approving protective equipment
- Investigating incidents involving lasers
- Maintaining records pertinent to the Laser Safety Program
- Supplying laser hazard signs and labels
- Office of Environment, Health, & Safety

THE OFFICE OF ENVIRONMENT, HEALTH & SAFETY (EH&S)

EH&S is tasked with providing personnel and resources to support the Laser Safety Officer (LSO) in their mission.

DEPARTMENT CHAIRPERSONS

Department chairpersons must ensure that Principal Investigators (PIs) within their department adhere to all directives and compliance requests from the LSO and EH&S concerning the Laser Safety Program.

PRINCIPAL INVESTIGATORS

PIs bear direct responsibility for executing the Laser Safety Program. Their duties encompass enforcing hazard controls, managing non-laser related risks, and notifying the LSO of any changes impacting laser users. PIs are also responsible for ensuring that all laser users:

- Maintain a safe work environment.
- Participate in mandatory laser safety training and refresher courses.
- Register all laser users with the LSO.
- Ensure compliance with all parts of the Laser Safety Program by those under their supervision.
- Verify that all users have completed the required campus laser safety training.
- Develop comprehensive Standard Operating Procedures (SOPs) covering all aspects of laser operation, from setup and alignment to maintenance, repairs, and incident reporting.
- Confirm that all users have:
  - Completed online laser safety training,
  - Received practical, hands-on training with the specific laser system,
  - Are informed about associated safety precautions,
  - Have reviewed the relevant SOPs,
  - Commit to using laser protective eyewear appropriately.
  - Sign off on the SOPs after approval.
- Ensure the provision and use of appropriate Personal Protective Equipment (PPE).

- Report any laser-related eye exposure incidents to the LSO within 24 hours.
- Inform the LSO of any new acquisitions, transfers, or disposals of lasers.
- Ensure that laser use areas are clearly marked with appropriate laser hazard warning signs.
- Notify the LSO of any alterations in experiments or facilities that could affect safety.

LASER USERS

Before operating any Class 3B or Class 4 laser, all users must complete the required laser safety training. Users are accountable for adhering to the specific hazard controls and notification protocols outlined in their Laser Use Authorization (LUA). Their responsibilities include, but are not limited to:

- Attending the campus laser safety training session before unsupervised use of any Class 3B or Class 4 laser.
- Receiving relevant hands-on or on-the-job training.
- Reading, understanding, signing, and adhering to lab-specific laser standard operating procedures (SOPs).
- Using the correct Personal Protective Equipment (PPE) as stipulated by the campus Laser Safety Program.
- Promptly reporting any suspected eye exposures to the Principal Investigator (PI) or an Authorized User, or the LSO.
- Complying with additional campus or lab-specific safety procedures, requirements, or policies.
- Communicating any safety concerns to the PI or the LSO.

DEPARTMENT SAFETY REPRESENTATIVES

Department Safety Representatives (DSRs) have a key role in coordinating and encouraging safety and regulatory compliance. DSRs are the principal liaison between the employees/ staff/students in their department and campus service providers such as EH&S. DSRs are informed of any corrective actions found in facility audits.

LASER CLASSIFICATIONS

The hazard class of a laser is very important to determine what appropriate controls are needed to make the laser safe. The LSO must assure that all lasers at UCSB are properly classified as to their hazard class. All commercially-manufactured lasers come marked with the hazard class as required under the FDA Center for Devices and Radiological Health regulations. Lasers modified at UC Santa Barbara must be evaluated by the LSO and appropriately classed. It is the responsibility of the PI to assist the LSO by supplying the appropriate parameters of the laser system. The campus Laser Safety Program is designed for the oversight of Class 3B and Class 4 lasers only.

The most common classes of lasers are as follows:

CLASS 1

- Output a few microwatts
- Beam fully enclosed; incapable of causing eye or skin injury due to enclosure. They may contain a higher-class laser embedded within the unit that cannot be accessed in normal operations
- Exempt from additional control measures
- Example: Laser printers

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CLASS 1M

- Large diameter or divergent beams
- Same as Class 1 except they may be hazardous to view with the aid of optical instruments
- Examples: LEDs and bare laser diodes

CLASS 2 – LOW POWER VISIBLE

- Output < 1 mW in the visible portion of the spectrum (400-700 nm), and
- Eye protection is normally afforded by the aversion response
- Example: Supermarket style bar-code scanner.

CLASS 2M- MEDIUM POWER VISIBLE

- Same as Class 2 but may be hazardous if viewed with the aid of optical instruments

CLASS 3R- MEDIUM POWER VISIBLE (USED TO BE CALLED CLASS 3A)

- Output 1- 5mW visible and invisible range
- Only a hazard if viewed through optics or for long duration
- This laser will not pose either a fire hazard or diffuse-reflection hazard
- Example: Laser pointers

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CLASS 3B- INTERMEDIATE POWER CONTINUOUS WAVE OR PULSED- REQUIRES REGISTRATION WITH EH&S

- Output 5-500 mW visible and invisible range; pulsed or continuous wave
- May be hazardous under direct and specular reflection viewing conditions, but normally not a diffuse reflection or fire hazard; and
- It is a hazard to the eye or skin from the direct beam and eye protection is required, as well as barriers
- Example: Diode pump solid state lasers used for spectroscopy

CLASS 4 – HIGH POWER LASER- REQUIRES REGISTRATION WITH EH&S

- Output > 500 mW; visible and invisible range; pulsed or continuous wave
- A hazard to the eye or skin from the direct beam; it may also pose a diffuse reflection and fire hazard. Eye protection is required, as well as other barriers
- It may also produce laser generated air contaminants and hazardous plasma radiation
- Example: Nd:YAG laser used to pump a Ti- Sapphire laser

PROGRAM REQUIREMENTS/PROCEDURES

ACQUISITION, MODIFICATION, SALE OR TRANSFER OF LASERS

The Radiation Safety Office maintains an inventory of all Class 3B and 4 laser systems on campus to ensure that users are not exposed to harmful laser radiation and are operating these systems in compliance with the ANSI Standard. If you introduce a new laser to your workspace, please fill out the Laser Inventory Form and submit it to the Radiation Safety Office. Additionally, the Principal Investigator (PI) must notify the campus Laser Safety Officer (LSO) of any modifications, sales, or transfers involving Class 3B or 4 lasers. Note that these controls do not apply to other classes of lasers.

LASER SAFETY TRAINING REQUIREMENTS

INITIAL TRAINING

All individuals, including Principal Investigators (PIs), who intend to use a Class 3B or 4 laser are designated as "laser users" and must complete the initial laser safety training course provided by the campus. This e-course must be completed before anyone is allowed to operate any laser system. To enroll, laser users should visit the UC Learning Center website and search for "Laser Safety."

Additionally, the Principal Investigator (PI) is responsible for creating a safety-focused Standard Operating Procedure (SOP) and a Beam Alignment Procedure for all Class 3B and 4 laser systems, which must be approved by the campus Laser Safety Officer (LSO). Documentation is required to confirm that all users have completed their initial training and have read the SOP.

REFRESHER TRAINING

All laser users, including Principal Investigators (PIs), are strongly encouraged to refresh their knowledge of laser safety to maintain an up-to-date understanding of safe practices. PIs, along with individual laser users, should aim to attend refresher training every other year. Additionally, EH&S is available to provide this training directly to your group on-site.

SUSPECTED LASER INCIDENTS

Laser users are required to notify both the Principal Investigator (PI) and the Laser Safety Officer (LSO) within 24 hours of any suspected or confirmed laser incidents or exposures. The LSO will then investigate the incident, prepare a report for the PI, and keep records on all such events. Eye examinations will be arranged for all UC Santa Barbara personnel whenever a laser eye exposure is suspected.

Post-incident, the PI must ensure all necessary campus or departmental documentation is completed. The involved laser or laser system must remain out of use until the LSO has reviewed the incident, approved any corrective actions or recommendations, and given clearance to resume operations.

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STANDARD OPERATING PROCEDURES (SOPS)

For all active Class 3B and 4 lasers, a Standard Operating Procedure (SOP) is mandatory. The SOP must include:

- Hazard Description: Detailed explanation of the hazards and the control measures associated with the laser's operation.
- Eye Protection: Specifications for the required laser protective eyewear.
- Operational Procedures: Step-by-step procedures for:
    - Starting up and shutting down the laser
    - Aligning the laser
    - Servicing and maintaining the equipment
- Safety Precautions:
    - Checks for stray beams or unwanted reflections
    - Use of beam blocks
    - Preventing the beam from being on the same horizontal plane as the user's eyes
    - Use of beam enclosures
    - Mandatory use of protective eyewear
    - Requirements for hands-on training
- Emergency Response: Instructions on how to handle emergencies related to laser use.
- Non-User Safety: Procedures or instructions for non-laser users, such as maintenance staff, custodial workers, visitors, etc., who might enter the laser use area.
- Acknowledgment: An Authorized Laser User signature page where users acknowledge they have read and understood the SOP.

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SOPs must be:

- Reviewed and Approved: By both the Principal Investigator (PI) and the Laser Safety Officer (LSO).
- Accessible: A copy should be readily available for review at all times.
- Regularly Updated: PIs and laser users should review their SOPs annually or more frequently if there are changes in conditions.

An SOP template is accessible to campus users through the EH&S Laser Safety Program website.

PERSONAL PROTECTIVE EQUIPMENT (PPE)

The Principal Investigator (PI) must supply their laser users with appropriate laser eye protection and is accountable for ensuring it is worn whenever necessary. Laser eye protection is mandatory during beam alignments or whenever an open beam exceeds the Maximum Permissible Exposure (MPE) values set by ANSI Z136.1. Before purchasing any laser protective eyewear, the PI should consult with the Laser Safety Officer (LSO).

For certain uses, especially with ultraviolet (UV) lasers, skin protection might also be required, and the LSO will determine if this is necessary.

BEAM MANAGEMENT

Laser beam(s) must be restricted to the immediate location of use. Beams paths should be enclosed whenever practical. Beam stops/barriers must be used to terminate beams. The use of shutters, curtains, beam tubes, and other beam control devices are strongly encouraged. If the beam path cannot be enclosed, appropriate beam control measures (engineering and administrative) must be employed and detailed in the laser standard operating procedure. It is the responsibility of the PI and their laser users to verify that appropriate beam management is being practiced.

POSTING AND LABELING

All access points to the laser facility must be marked with ANSI standard laser hazard warning signs. Laser enclosures must be labeled to alert users to laser hazards as per the ANSI standard. Labels, laser hazard signs, and advice on their use are available from EH&S.

New or renovated campus laser facilities will be required to meet the campus laser safety design requirements. Design requirements for a Class 4 shall include illuminated laser hazard warning sign(s), laser rated curtain or barrier, emergency power off switch(s).

ACCESS CONTROL

For the entryway to a Class 3B Class 4 laser facilities, a door, blocking barrier, screen, curtain, etc. shall be used to block, screen, or attenuate the laser radiation at the entryway. The level of laser radiation at the exterior of these devices shall not exceed the applicable MPE, nor shall personnel experience any exposure above the MPE immediately upon entry.

Substitution of Alternate Control Measures (Class 3B or 4)

The ANSI Z136.1 Laser Standard (4.2) provides the LSO authority to substitute control measures specified in the standard for Class 3B and Class 4 laser or laser systems with other procedural, administrative, or alternate engineering control measures which provide equivalent protection.

ADMINISTRATIVE CONTROL MEASURES FOR CLASS 3B AND CLASS 4 LASERS

The following administrative controls are used for Class 3B and 4 lasers:

CLASS 3B & 4

- Access limited to authorized laser users
- Current laser safety training for all users
- Standard Operating Procedure
- Perform and document stray beam/unwanted reflection checks

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- Establish a Nominal Hazard Zone (NHZ)
- Post appropriate laser hazard warning sign at all entrances(s)
- Appropriate laser eye protection is required
- LSO may require additional control measures as needed*

* LSO has the authority to assign additional safety control measures (engineering/administrative/PPE) if needed

ENGINEERING CONTROL MEASURES FOR CLASS 3B AND CLASS 4 LASERS

The following engineered controls are used for Class 3B and 4 lasers:

CLASS 3B & 4

- Use of appropriate beam stop or attenuators and beam enclosures
- A door, blocking barrier, screen, curtain, etc. shall be used to block, screen, or attenuate the laser radiation at the entryway
- All windows, doorways, open portals, etc., from an indoor facility either covered or restricted
- LSO may require additional control measures as needed*

* LSO has the authority to assign additional safety control measures (engineering/administrative/PPE) if needed

NON-BEAM / ANCILLARY HAZARDS

It is important to address other hazards associated with the use of lasers beyond eye or skin hazards. Non-beam hazards include physical and chemical hazards:

PHYSICAL HAZARDS:

- Electrical Hazards: High voltages used in laser power supplies can lead to electric shock or fires.
- Mechanical Hazards: Rotating parts, moving stages, or the potential for equipment to tip over.

- Noise: From cooling systems or operation of the laser which might require hearing protection.
- Ergonomic Hazards: Improper workstation setup leading to strain or repetitive stress injuries.
- Thermal Burns: From touching hot laser components or surfaces.

CHEMICAL HAZARDS:

- Laser Gases: Exposure to gases used in laser systems, like CO2 or excimer lasers, which can be toxic or asphyxiating.
- Dye Solutions: Used in some lasers, which might be toxic or carcinogenic.
- Cooling Agents: Exposure to chemicals used in cooling systems, such as ethylene glycol in some laser cooling systems.
- Fumes and Vapors: Generated from laser interaction with materials, especially in cutting or engraving processes, potentially releasing harmful substances.

ANCILLARY HAZARDS:

- Fire Risk: Particularly with high-power lasers, where ignition of materials can occur.
- Explosion Risk: From the rupture of laser tubes or containers under pressure.
- Radiation Hazards: Not from the laser itself but from associated equipment like x-ray tubes in some laser systems.
- Cryogenic Hazards: If liquid nitrogen or other cryogens are used for cooling, there's risk of frostbite or asphyxiation.
- Optical Radiation: From ancillary light sources used in alignment or diagnostic tools.

These non-beam and ancillary hazards require careful consideration in the safety protocols for any laser setup to ensure a comprehensive safety program.

Appendix A:

SELECTION OF LASER SAFETY EYEWEAR

Appropriate laser protective eyewear must be worn during beam alignments or whenever an open beam exceeds the Maximum Permissible Exposure (MPE) value as defined by ANSI Z136.1. All eyewear should be clearly labeled with its optical density and the wavelength(s) it protects against.

Generally, eyewear is not required for Class 2 or 3R lasers or laser systems unless viewed through optical aids which could increase the hazard.

FACTORS FOR SELECTING EYEWEAR INCLUDE:

- Laser Power and/or Pulse Energy: The strength of the laser output.
- Wavelength(s) of Power Output: To ensure protection against the specific wavelengths emitted.
- Potential for Multi-Wavelength Operations: Eyewear should cover all relevant wavelengths if multiple are used.
- Radiant Exposure or Irradiance Levels: Protection against the worst-case scenario exposure.
- Exposure Time Criteria: How long one might be exposed to the laser beam.
- Maximum Permissible Exposure (MPE): Ensuring the eyewear meets or exceeds this standard.
- Optical Density Requirement: The eyewear's ability to attenuate laser light at specific wavelengths.
- Angular Dependence of Protection: How the protection varies with the angle of incidence.
- Visible Light Transmission: Balancing the need for protection with the ability to perform tasks while wearing the eyewear.

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- Side-Shield Protection: The necessity for side shields to prevent peripheral exposure, considering maximum peripheral vision requirements.
- Laser Pulse Characteristics: Including considerations for transient bleaching with ultra-short pulses.
- Prescription Glasses: Availability of prescription options.
- Comfort and Fit: Ensuring the eyewear is comfortable for extended use.
- Degradation of Filter Media: Monitoring for photo-bleaching or other degradation over time.
- Strength of Materials: Durability against mechanical damage or shock.
- Specular Reflection: Preventing the front surface of the eyewear from creating hazardous reflections.
- Anti-Fogging: Design and coatings to prevent fogging which could impair vision.

MAINTENANCE AND INSPECTION:

- Eyewear should be inspected before each use for any signs of damage or dirt and replaced if compromised.
- Consult the Laser Safety Officer (LSO) for assistance in selecting the appropriate eyewear.

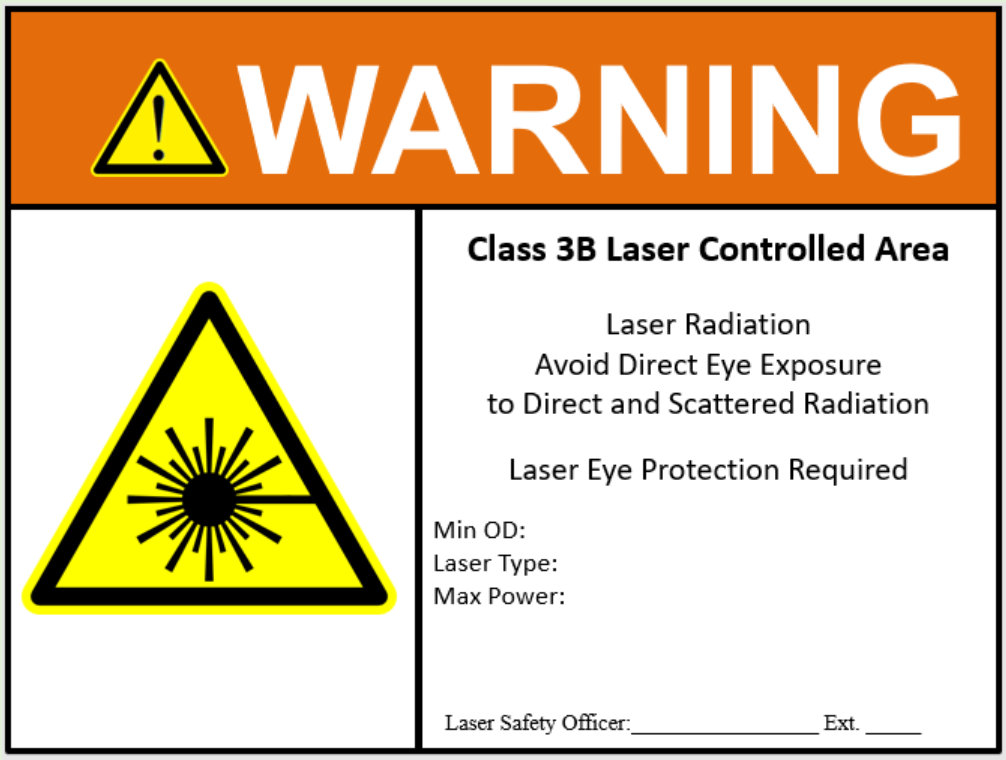
By considering these factors, one can ensure that the chosen laser safety eyewear provides adequate protection while allowing for safe and effective use of laser systems.

Appendix B:

LASER HAZARD WARNING, DANGER AND NOTICE SIGNS

Laser hazard signs must be prominently displayed to alert individuals to potential dangers. The appropriate warning or danger signs should be placed at all entry points to laser-controlled areas. If the Laser Safety Officer (LSO) deems it necessary, additional signs should be posted within these areas as well. Laser hazard warning, danger, or notice signs and labels (excluding lighted hazard warning signs) are supplied by the LSO or can be accessed through the EH&S website.

Standard laser WARNING sign for a Class 3B laser.



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Standard laser WARNING sign for a Class 4 laser.

Standard laser DANGER sign for a Class 4 laser.

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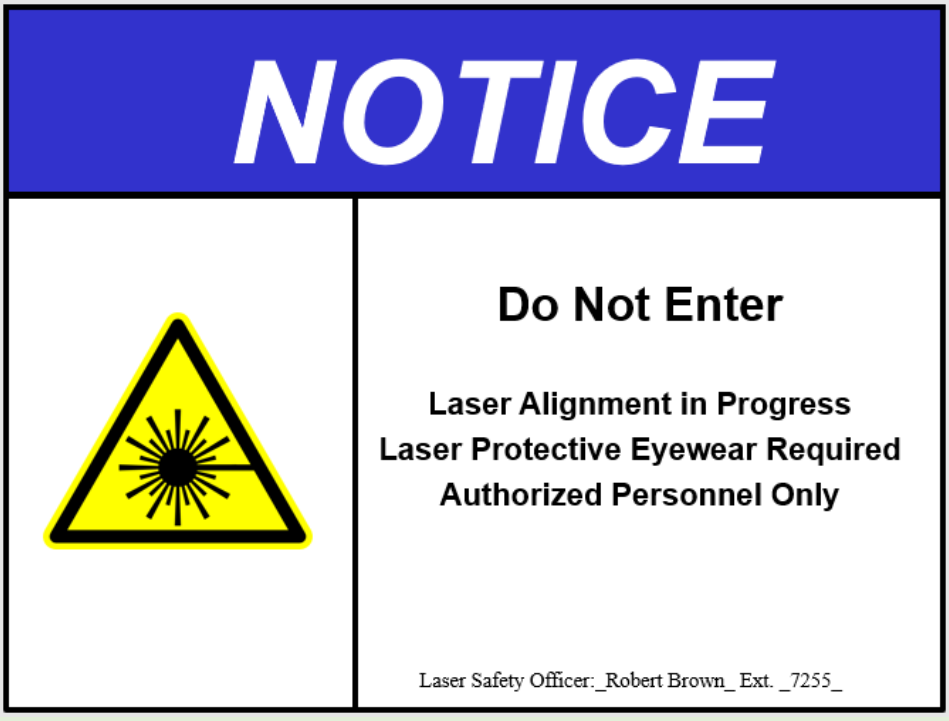
Standard NOTICE Unattended Laser *sign is required when lasers are being operated and not attended.*

Standard ***NOTICE Alignment in Process*** *sign is required when beam alignment is in-process.*



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