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Laser Safety Manual

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A. Scope

UNC Charlotte requires that all lasers and laser systems be operated in accordance with the American National Standards Institute (ANSI) Z136.1 – 2014, "American National Standard for Safe Use of Lasers" and ANSI Z136.8 – 2021, "American National Standard for Safe Use of Lasers in Research, Development, or Testing", as well as other applicable federal and state regulations. The ANSI Z136.1 and ANSI Z136.8 standards provide recommendations for the safe use of laser

The University will use an application-specific standard. This is accomplished by classifying lasers according to their hazard level and then implementing control measures based on the hazards and conditions of use. The hazard classification is based on the risk of biological damage the laser may cause to eyes and/or skin. Non-beam hazards (e.g., electrical) are not included in the classification, but will be addressed in a separate section (Appendix V). ANSI Z136.1 sets forth the current hazard classifications.

B. Laser Safety Program

UNC Charlotte has the responsibility to provide a safe working environment for faculty, staff, and students. Principal Investigators and researchers working with lasers are responsible to ensure lasers are operated safely and laser hazards are controlled adequately. The Laser Safety Program has been designed to fulfill these responsibilities through:

- Designation of a Laser Safety Officer and Deputy Laser Safety Officer
- Departmental and Personnel Responsibilities
- Hazard Classification
- Administrative and Engineering Controls
- Training

C. Responsible Parties

1. Laser Safety Officer (LSO)

The Laser Safety Officer (LSO, Brian Stewart) is appointed by the Director of Environmental Health and Safety (EHS). The LSO is responsible for managing the laser safety program, monitoring safety control measures for laser hazards and taking steps necessary to control and mitigate those hazards. The LSO or designee, through the EHS Office will also:

i. Provide education to authorized laser users in the safe operation of lasers systems.
ii. Assist in providing protective measures – including warning signs and labels, PPE guidance, administrative and engineering control consultations.
iii. Periodically audit lasers use facilities.
iv. Investigate laser accidents and implement plans and procedures to prevent reoccurrences.
v. Maintain inventory of Class 3b and Class 4 lasers and laser systems.

A Deputy Laser Safety Officer (DLSO, Linda Robles) will be appointed by the Director of EHS and the LSO. The Deputy will assist the LSO, as needed, and will perform the functions of the LSO when the LSO is unavailable.

2. Departments

Supervisors/ Principal Investigators (PI):

i. Submit an initial **Laser Registration Form (Appendix I)** to the LSO for each Class 3b and Class 4 laser or laser system.
ii. When placing new lasers or moving existing ones the PI should identify laser hazards present in the work area using the **Laser Hazard Assessment (Appendix II)**, and implement appropriate hazard controls, including ANSI approved signs and labels.
iii. Develop and submit to the LSO the current Standard Operating Procedures (SOPs) for each Class 3b and Class 4 laser or laser system using the **Laser Registration Form (Appendix I)** as a guide.
iv. Participate in laser safety inspections provided by EH&S. Please see **Appendix III** for template.
v. Identify all authorized personnel who are eligible to operate or maintain a Class 3b or Class 4 laser or laser system.
vi. Ensure general laser safety training is provided to each laser user (to include the physical hazards, health hazards, and emergency procedures) PIs should provide specific laser safety training to all users on individual lasers and document using the **Laser Registration Form (Appendix I)**.
vii. Designate a Laser Safety Contact (LSC) for each laser or laser system.
viii. Ensure that laser users follow established safety procedures.
ix. Keep copies of all current SOPs, trainings, and inspections/investigations.
x. Maintain a copy of this written program in the workplace.

3. Laser User:

i. Know the hazards and the precautionary procedures for laser use in their work area.
ii. Attend required training(s).
iii. Plan and conduct operations in accordance with established procedures and good safety practices.
iv. Use personal protective equipment in accordance with prescribed training.

D. Hazard Classification

Lasers are divided into several classes depending upon the power or energy of the beam and the wavelength of the emitted radiation. Laser classification is based on the laser's potential for causing immediate injury to the eye or skin and/or potential for causing fires from direct exposure to the beam or from reflections from diffuse reflective surfaces.

Labels are to be placed on the laser system to positively identify the hazard classification. Commercially produced laser systems are labeled by the manufacturer (if manufactured after August 1976). It is to be noted that the classification may change if the laser is modified. The LSO and laser users must be notified if the hazard class altered, and the label must be modified to reflect the change.

1. Laser System Classes, Hazards, and Requirements

Lasers and laser systems are characterized by hazard into four main categories. These are based on the potential for causing biological damage. The chart below describes the classification, warnings, labels, and hazards for each, as well as the requirements of each class.

Class 1 laser system:

Considered to be incapable of producing damaging radiation levels during operation and exempt from any control measures.

Class 1M laser system:

Considered to be incapable of producing hazardous exposure conditions during normal operation unless the beam is viewed with collecting optics (e.g., telescope) and is exempt from any control measures other than to prevent potentially hazardous optically aided viewing.

Class 2 laser system:

Emits in the visible portion of the spectrum (400 nm to 700 nm) and eye protection is normally afforded by the aversion response.

Class 2M laser system:

Emits in the visible portion of the spectrum (400 nm to 700 nm) and eye protection is normally afforded by the aversion response for unaided viewing. However, Class 2M is potentially hazardous if viewed from collecting optics (e.g., telescope)

Class 3R laser system:

Has reduced control requirements and is potentially hazardous under some direct and specular reflection viewing conditions if the eye is appropriately focused and stable, but the probability of an actual injury is small. This laser will not pose either a fire hazard or diffuse reflection hazard

Class 3B laser system:

May be hazardous under direct and specular reflection viewing conditions, but is normally not a fire hazard, diffuse reflection hazard, nor a laser generated air contaminate (LGAC) production hazard.

Class 4 laser system:

Is a hazard to the eye or skin from the direct bean, may pose a fire hazard or diffuse reflection hazard, and may also produce LGAC and hazardous plasma radiation.

ANSI Classification	Class 1		Class 2		Class 3		Class 4
Sub Class	*Class 1*	*Class 1M*	*Class 2*	*Class 2M*	*Class 3R*	*Class 3B*	*Class 4*
Visible light laser power	<0.039mW, or beam is inaccessible		<1 mW		<5mW	<500mW	>500mW
Warning Indicator	None required		None required		CAUTION	WARNING	DANGER
Label Text		DO NOT VIEW DIRECTLY WITH OPTICAL INSTRUMENTS	DO NOT STARE INTO BEAM	DO NOT STARE INTO BEAM OR VIEW DIRECTLY WITH OPTICAL INSTRUMENTS	AVOID DIRECT EYE EXPSOSURE	AVOID EXPOSURE TO BEAM	AVOID EYE OR SKIN EXPOSURE TO DIRECT OR SCATTERED RADIATION
Hazards	**Class 1**		**Class 2**		**Class 3**		**Class 4**
Sub Class	*Class 1*	*Class 1M*	*Class 2*	*Class 2M*	*Class 3R*	*Class 3B*	*Class 4*
Eye hazard	Safe for long-term intentional viewing	Safe for unaided eye exposure. May be hazardous with binoculars, eye loupes, or other optical instruments.	Safe for unintentional exposure less than 1/4 second. Do not stare into beam.	Safe for unintentional, unaided eye exposure of less than 1/4 second. May be hazardous with binoculars, eye loupes, or other optical instruments.	Unintentional or accidental exposure to direct or reflected beam has low risk. Avoid intentional exposure.	Eye hazard. Avoid exposure to direct or reflected beam.	Severe eye hazard. Avoid exposure to direct or reflected beam.
Skin burn hazard	None		None		None	Can heat skin if beam contacts skin at close range.	Can instantly burn skin. Avoid direct exposure to beam.
Material burn hazard	None		None		None	Can burn materials if beam contacts substance at close range	Can instantly burn materials. Avoid beam contact with materials that may burn.
Requirements	**Class 1**		**Class 2**		**Class 3**		**Class 4**
Sub Class	*Class 1*	*Class 1M*	*Class 2*	*Class 2M*	*Class 3R*	*Class 3B*	*Class 4*
Control Measures	Not required	Required	Not required[b]	Required	Not required[b]	Required	Required
Training	Not required	Application Dependent[a]	Not required[b]	Application Dependent[a]	Not required[b]	Required	Required
LSO	Not required	Application Dependent[a]	Not required	Application Dependent[a]	Not required[b]	Required	Required
Engineering Controls	Not required	Application Dependent[a]	Not required[b]	Application Dependent[a]	Not required[b]	Required	Required

[a] Certain uses of Class 1M or Class 2M lasers or laser systems that exceed Class 1 or Class 2 because they do not satisfy measurement Condition 1 may require hazard evaluation and/or manufacturer's information

[b] Not required except for conditions of intentional intrabeam exposure applications.

E. Control Measures

1. General Control Considerations

Control measures for lasers are devised to reduce the possibility of eye and skin exposure to hazardous levels of radiation and to other hazards associated with laser systems during operation, use and maintenance. For all laser use in restricted or controlled areas, controls must ensure the applicable maximum permissible exposure (MPE) limit is not exceeded. The MPE is the level of laser radiation to which an unprotected person may be exposed without adverse biological changes in the eye or skin. It is a function of wavelength and duration of exposure.

Control measures include administrative and engineering controls. Administrative controls include training, standard operating procedures, and work practices. Engineering controls are items incorporated into the laser system to reduce or eliminate the chance of exposure.

F. Administrative Controls

1. Standard Operating Procedures

Standard Operating Procedures (SOPs) for Class 3B and Class 4 lasers are required. The SOPs are to be reviewed and approved by the LSO, and a copy is to be kept with the laser equipment as reference for operators.

2. Training

Training in the proper operation of lasers is in place to make sure laser users have a thorough understanding of laser hazards and the appropriate control measures. Laser users working with Class 3B or 4 lasers must complete preliminary laser safety training prior to working in the lab with a laser system. Additional training will occur under the direct supervision of an experienced, trained operator who will monitor the laser user trainee to ensure safe operation and terminate laser emission in case of equipment malfunction or other unsafe condition. All training must be documented and available upon inspection.

3. Authorized Personnel

Only authorized personnel may operate, maintain or service Class 3B and Class 4 laser systems. The LSO or PI will make the determination as to who is deemed authorized to work with lasers. Authorized personnel must have completed basic laser safety training, in-person training under the supervision of a trained operator and must be deemed competent by the PI or trained operator.

4. Indoor Laser Control Area (LCA)

The Laser control area is where occupancy and activity of individuals within is subject to control and supervision for the purpose of protection from laser hazards.

a. The Class 3B and Class 4 LCA shall:

1. Be controlled to permit lasers and laser systems to be operated only by trained personnel.
2. Be posted with appropriate warning signs at the entry and within the LCA if deemed appropriate.
3. Operated with a well-defined path.
4. Be well-defined and controlled if the laser beam must extend outdoors and projects into controlled airspace.

b. The Class 3B and Class 4 LCA should:

1. Be under direct supervision of a knowledgeable individual.
2. Provide limited access to spectators and require approval for entry.
3. Utilize beam stops to stop hazardous beams.
4. Have only diffusely reflecting material in or near beam path.

5. Provide appropriate eye protection
6. Ensure exposed beam is above or below eye level of standing or sitting personnel.
7. Cover or restrict windows, doorways, portals to reduce the transmitted laser radiation to levels at or below MPE.
8. Prevent unauthorized use.

c. Class 4 LCA shall:

Provide entryway safety controls designed to always allow both rapid egress by laser personnel and admittance to the laser-controlled area under emergency situations.

The Class 4 LCA shall be designed to fulfill all items listed for Class 3B, and in addition, shall incorporate one of the following alternatives:

a) *Non-defeatable (non-override) Area or Entryway Safety Controls*. Using non-defeatable safety latches, entryway or area interlocks shall be used to deactivate the laser or reduce power below MPE in the event of unplanned entry to the LCA.
b) *Defeatable Area of Entryway Safety Controls.* Defeatable latches, entryway or area interlocks may be used if non-defeatable safety control systems will limit the intended use of the laser; only if it is clear there is no laser radiation hazard at the point of entry.
c) Procedural Area or Entryway Safety Controls. Where safety latches or interlocks are impractical or inappropriate (e.g., limited open beam paths, fiber operations, and enclosed beam paths) the following shall apply:
    i. All authorized personnel shall be trained, and PPE shall be provided upon entry.
    ii. A means shall be used to block, screen, or attenuate the laser radiation at the entryway. The level of the laser radiation exterior to these devices shall not exceed the applicable MPE, nor shall personnel experience any exposure above the MPE immediately upon entry.
    iii. At the entryway there shall be an activation warning system indicating that the laser is energized and operating at Class 4 levels.

5. Temporary Laser Controlled Area – TLCA

A TLCA will occur when panel removal or entry to the Nominal Hazard Zone (NHZ) becomes necessary and the accessible radiation exceeds the MPE. The TLCA will require all safety requirements for personnel both within and outside the NHZ, and a Notice sign shall be posted outside the TLCA to warn of the potential hazard.

6. Outdoor Control Measures

All Class 3B and Class 4 lasers used outdoors shall meet the following requirements:

a. The LSO shall establish the NHZ if not provided as part of the documentation supplied by the laser manufacturer.
b. If visible lasers are used at night, the LSO shall determine if the laser beams will visually interfere with critical tasks. Visual interference occurs well below the MPE.
c. The NHZ shall be clearly marked with laser warning signs and demarcated as a laser hazard area.
d. All personnel entering the area shall be trained.
e. Only authorized personnel will operate the laser.
f. Combinations of physical barriers, screens and PPE shall be provided and used by persons authorized to enter the NHZ
g. Appropriate administrative controls will be established if personnel are allowed within the NHZ.
h. Directing the laser beam toward automobiles, aircraft, or other manned structures or vehicles shall be prohibited unless adequate training and PPE is provided and used by all affected personnel or as authorized by the LSO and permitted by FAA Order 7400.2.
i. The exposed laser bean shall not be maintained at eye level without specific authorization from the LSO.
j. The laser beam shall be confined and terminated wherever possible.
k. When the laser is not being used it shall be disabled to prevent unauthorized use.

The operation of Class 4 lasers during rain, snow, fog, or dusty atmospheric conditions may produce scattering of the beam. During these conditions, conditions must be evaluated by the LSO to determine if additional precautions or PPE are required.

7. Laser in Navigable Airspace

Laser experiments or programs that will involve the use of lasers within navigable airspace must be coordinated with:

Federal Aviation Administration
Flight Standards District Office
3800 Arco Corporate Drive
Charlotte, NC 28273
(704) 319-7020

Additionally, laser light shows demonstrations that use Class 3B or Class 4 lasers systems shall coordinate with the Food and Drug Administration (FDA) before use.

8. Alignment and Open Beam Procedures

It is strongly recommended that lower power (Class 1, Class 2, Class 3R) visible lasers be used during alignment procedures to simulate the path of higher power lasers. If this is not possible, alignments of Class 3 and Class 4 lasers must be managed to prevent primary beams, specular or diffuse reflection beams from contacting eyes or skin above MPE.

During service, testing or repair, beam attenuators should be placed over the beam aperture to reduce the level of laser radiation to below the MPE.

Additional alignment procedures can be found in Appendix VI

9. Beam Height

Beam height should be set at a level that is not the normal position of the eye of an individual in a standing or seated position. If this is unavoidable, additional controls are required to protect individuals at these locations.

10. Visitors and Spectators

Visitors and Spectators shall be permitted within a Class 3B or Class 4 laser control area only when all the following have been met:

a) Approval from PI has been obtained
b) Hazard avoidance has been explained
c) The NHZ has been explained
d) Appropriate PPE and barriers are in use
e) Must be under direct supervision of the authorized operator who must make visual surveillance of conditions for safe use.
f) The LSO has approved the SOP for visitor access.

11. Service Personnel

Service personnel must comply with the appropriate control measures when servicing laser systems. The LSO shall confirm that the service personnel have the experience and safety training commensurate with the class of laser system to be serviced. This may be in the form of a safety plan from the vendor.

Administrative (and Procedural) Control Measures	Classification						
	1	1M	2	2M	3R	3B	4
Standard Operating Procedures (4.4.3.1)	—	—	—	—	—	•	X
Output Emission Limitations (4.4.3.2)	—	—	—	—	LSO Determination		
Education and Training (4.4.3.3)	—	•	•	•	•	X	X
Authorized Personnel (4.4.3.4)	—	—	—	—	—	X	X
Indoor Laser Controlled Area (4.4.3.5)	—	◦	—	◦	—	X NHZ	X NHZ
Class 4 Laser Controlled Area (4.4.2.9 and 4.4.3.5)	—	—	—	—	—	—	X
Temporary Laser Controlled Area (4.4.3.5)	∇ MPE	∇ MPE	∇ MPE	∇ MPE	∇ MPE	—	—
Controlled Operation (4.4.3.5.2.1)	—	—	—	—	—	—	•
Outdoor Control Measures (4.4.3.6)	X	◦ NHZ	X NHZ	◦ NHZ	X NHZ	X NHZ	X NHZ
Laser in Navigable Airspace (4.4.3.6.2)	•	•	•	•	•	•	•
Alignment Procedures (4.4.3.8)	∇	X	X	X	X	X	X
Spectators (4.4.3.7)	—	◦	—	◦	—	•	X
Service Personnel (4.4.3.9)	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

(Table from ANSI Z136.1-2014)

G. Engineering Controls

1. Protective Housing

Whenever possible, protective housing should be used to enclose the beam. By engineering the device to prevent access to the beam, the laser system will fall under Class 1, and will not require additional controls. If the housing is removed during research or maintenance, the laser will no longer meet the Class 1 standard. In this case, a hazard analysis will need to be performed and the laser system will need to be classified based on the laser power. Additional controls will need to be implemented, including:

- Additional training
- Laser control area (LCA)
- Eye Protection
- Barriers and beam stops
- Administrative controls

2. Safety Interlocks and Service Panels

The protective housing must be interlocked to cut power to the laser if the housing is removed. Interlocks are not to be overridden or defeated during normal laser operation. Service panels must also be interlocked and be marked with a warning label.

3. Master Switch Controlled Access

Class 3B and Class 4 lasers should have a master switch for beam termination and system shut-off. Access to the master switch can be a key switch, coded access, or equivalent measure. Only authorized personnel may have access to the master switch, and it must be secured to prevent unauthorized use.

The master switch must be designed to allow for OSHA required lockout/tagout procedures.

4. Windows, Diffuse Display Screens, Collecting Optics

All viewing windows, display screens, and collecting optics (lenses, telescopes, microscopes, etc.) must ensure the laser radiation at the viewing position is at or below the MPE. This can be accomplished through interlocks, filters, attenuators, or other suitable methods. The material chosen for viewing windows and displays must not support combustion or release Laser Generated Air Contaminants (LGAC) above OSHA limits.

5. Beam Paths

a. Beam Stops

Class 3B and Class 4 lasers are to have beam stops in place. Typically, these are permanently mounted on the unit. An attenuator may also be used if the beam power is reduced to MPE. Additional stops may be required to maintain the beam within the experimental area.

b. Open Beam Paths

A laser hazard assessment will be performed by the PI whenever a Class 3B or Class 4 laser is unenclosed. The assessment may be dependent on the nature of the environment, geometry of the application, or spatial limitations of other hazards associated with the laser. Appendix II is available for the PI to utilize and keep record of a hazard assessment. LSO is available to assist if needed.

Often the assessment will define an extremely limited NHZ, and procedural controls will be adequate for protection. Class 1 conditions will be fulfilled when:

1. For limited open beam path lasers where analysis confirms the accessible levels during operation are below MPE, and

2. Where limited open beam paths are such that human access of placement of a tool as part of normal operation is restricted.

c. Enclosed Beam Path

When the entire beam path is enclosed, preventing human access to radiation above Class 1 MPE, no further controls are required.

Protective housing requirements are still in place and should be interlocked or have an alternate set of controls approved by the LSO to prevent unauthorized removal.

6. Activation Warning and Emission Delay

Within the laser control area, an audible alarm, warning light, or verbal countdown must be used during activation or startup of a Class 3B or Class 4 laser. A warning light outside the control area must also be activated when using Class 3B or Class 4 lasers.

Adequate time (emission delay) must be provided for individuals to take precautions from the activation of the warning to the emission of laser radiation.

7. Controlled Areas

A controlled area must be designated for all open beam paths. The controlled area is the area where laser radiation exceeds the MPE. Appropriate control measures must be implemented in laser-controlled areas to prevent radiation exposure.

8. Entryway Controls

Never direct a beam toward an entryway. Locking entryway doors as a means of access control is not acceptable because it is contrary to the principle of permitting rapid egress or emergency access. Entry to rooms containing Class 4 lasers and laser systems must be interlocked with the laser to prevent unexpected entry of personnel while the laser is in operation. The PI shall implement one of the following three mechanisms to protect personnel:

a. Non-defeatable entryway

Non-defeatable entryway controls (safety latches and entryway or area interlocks such as electrical switches, pressure sensitive floor mats, or motion detectors) shall be used to deactivate the laser or reduce the output levels to less than MPE should unauthorized entry into the laser area occur.

b. Defeatable Entryway

Defeatable entryway controls (safety latches and entryway or area interlocks) shall be used if the controls in the previous paragraph adversely affect the intended use of the laser or laser system. If there is no laser light hazard at the entry point, the interlock may be bypassed to allow access to authorized personnel provided they have been adequately trained and provided with adequate personal protective equipment.

c. Procedural Entryway Controls

Where the above entryway safety controls are not practical or are inappropriate, the following shall apply:

i. All authorized personnel shall be trained, and proper personal protective equipment shall be available upon entry.
ii. A secondary barrier (laser curtain, wall, or partition) shall be used to block the laser radiation at the entryway. This secondary barrier will intercept a beam or scatter so that a person entering the room cannot be exposed above MPE limits.
iii. At the entryway there should be a visible or audible indication that the laser is in operation. Existing installed laser-warning signs or flashing lights may satisfy this requirement.

9. Protective Barriers and Curtains

Using a blocking barrier or curtain can be used to block or filter laser beam at an entryway of a controlled area. The barrier shall be selected to withstand direct and diffusely scattered beams. Consider flammability and decomposition products when selecting a barrier material. It is essential that the barrier does not support combustion or release LGAC after exposure to a laser.

Engineering Control Measures	Classification						
	1	1M	2	2M	3R	3B	4
Protective Housing (4.4.2.1)	X	X	X	X	X	X	X
Without Protective Housing (4.4.2.1.1)	LSO shall establish Alternative Controls						
Interlocks on Removable Protective Housings (4.4.2.1.3)	∇	∇	∇	∇	∇	X	X
Service Access Panel (4.4.2.1.4)	∇	∇	∇	∇	∇	X	X
Key Control (4.4.2.2)	—	—	—	—	—	•	•
Viewing Windows, Display Screens and Diffuse Display Screens (4.4.2.3)	Ensure viewing limited < MPE						
Collecting Optics (4.4.2.6)	X	X	X	X	X	X	X
Fully Open Beam Path (4.4.2.7.1)	—	—	—	—	—	X NHZ	X NHZ
Limited Open Beam Path (4.4.2.7.2)	—	—	—	—	—	X NHZ	X NHZ
Enclosed Beam Path (4.4.2.7.3)	Further controls not required if 4.4.2.1 and 4.4.2.1.3 fulfilled						
Area Warning Device (4.4.2.8)	—	—	—	—	—	•	X
Laser Radiation Emission Warning (4.4.2.9)	—	—	—	—	—	•	X
Class 4 Laser Controlled Area (4.4.2.10 and 4.4.3.5)	—	—	—	—	—	—	X
Entryway Controls (4.4.2.10.3)	—	—	—	—	—	—	X
Protective Barriers and Curtains (4.4.2.5)	—	—	—	—	—	•	•

LEGEND:
X Shall
• Should
— No requirement
∇ Shall if enclosed Class 3B or Class 4
NHZ Nominal Hazard Zone analysis required

(Table from ANSI Z136.1-2014)

H. Personal Protective Equipment

Laser beam enclosure is the preferred method of protection for laser operators. However, it may be necessary to use PPE when other control measures do not provide adequate means to prevent access to direct or reflected beams at levels above the MPE.

1. Protective Eyewear

Wear approved laser protective eyewear specifically designed for the type of laser to be used whenever working in a Class 3B or Class 4 laser-controlled area. Laser protective eyewear is usually not required for Class 2 or Class 3R lasers or laser systems, except in conditions where intentional long-term (>0.25 seconds) direct viewing is required. Eyewear must be specifically selected to withstand either direct or diffusely scattered beams and shall meet all provisions of ANSI Z87.1-2020.

Even when the accessible radiation levels are considered safe, it is good practice for personnel to always wear eye protection when operating lasers.

Laser eyewear should not be subjected to high-intensity beams. High average intensity and high peak intensity beams can physically damage the lenses, resulting in loss of eye protection.

Factors in selecting appropriate eyewear:

1. Laser power and /or pulse energy
2. Wavelength(s) of laser output
3. Potential for multi-wavelength operation
4. Radiant exposure or irradiance levels for which protection (worst case) is required
5. Exposure time criteria
6. Maximum permissible exposure
7. Optical density requirement of eyewear filters at laser output wavelength
8. Angular dependence of protection afforded
9. Visible light transmission requirement and assessment of the effect of the eyewear on the ability to perform tasks while wearing the eyewear
10. Need for side-shield protection and maximum peripheral vision requirement
11. Radiant exposure or irradiance and the corresponding time factors at which laser safety filter characteristics change occurs, including transient bleaching especially for ultra-short pulse lengths
12. Need for prescription glasses
13. Comfort and fit
14. Degradation of filter media, such as photo bleaching
15. Strength of materials (resistance to mechanical trauma and shock)
16. Capability of the front surface to produce a hazardous specular reflection
17. Requirement for anti-fogging design or coatings

a. Labeling of Protective Eyewear

All eyewear must be clearly labeled with optical density and wavelength. Color-coding or other distinctive identification is recommended in multi-laser environments.

b. Care and Maintenance

Proper care and maintenance are essential to ensure that the equipment remains in good condition. Clean eyewear following manufacturer recommendations. Do not use harsh or abrasive chemicals that may damage the integrity of the eyewear.

c. Inspection

Eyewear inspections shall be conducted periodically. Inspect the lens material for pitting or cracking and inspect the goggle frame for mechanical integrity and light leaks. Straps should be inspected as well and replaced if they have been stretched or are frayed. Do not attempt to repair protective eyewear. Damaged eyewear should be disposed of immediately to prevent possible injury to the wearer.

2. Skin Protection

When there is a possibility of exposure to laser radiation greater than the MPE for skin, LUs are required to use protective gloves, clothing, and shields. Skin protection can best be achieved through engineering controls. 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. Use 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.).

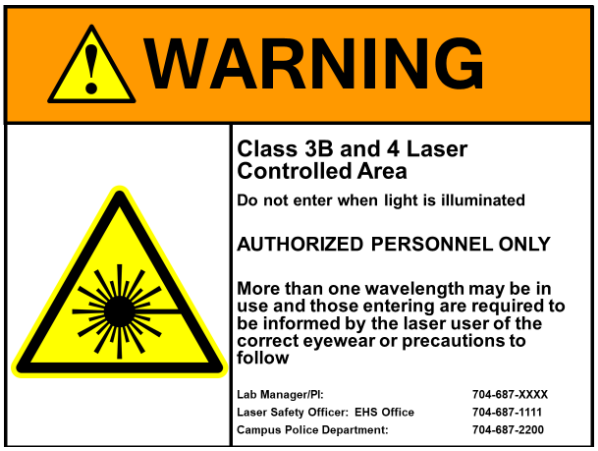
Personal Protective Equipment PPE	**Classification**						
	1	1M	2	2M	3R	3B	4
Laser Eye Protection (4.4.4.1)	—	—	—	—	—	X	X
Skin Protection (4.4.4.3)	—	—	—	—	—	•	•
Protective Clothing (4.4.4.1 and 4.4.4.3.1)	—	—	—	—	—	•	•

LEGEND: X Shall
• Should
— No requirement

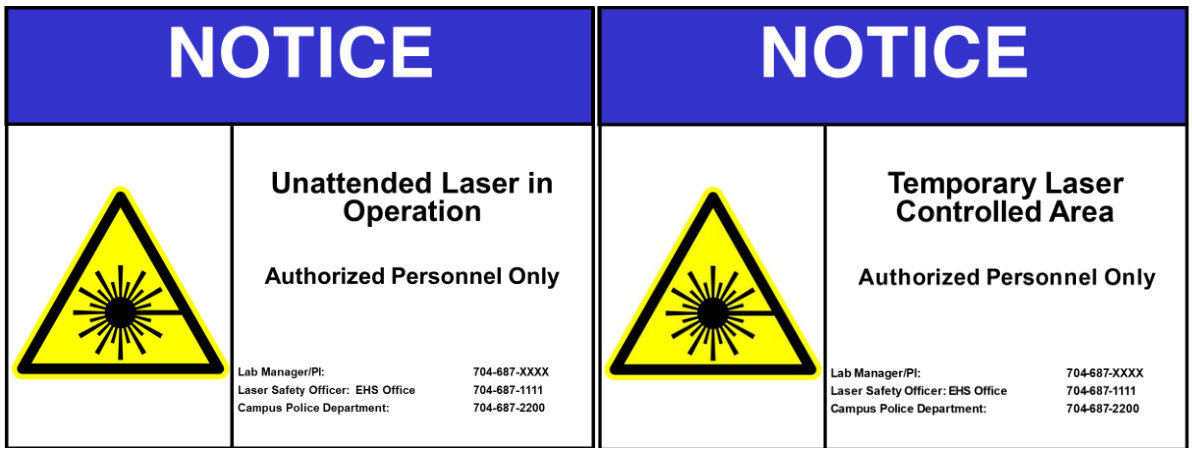
(Table from ANSI Z136.1-2014)

I. Warning Signs and Labels

Class 3B or Class 4 Laser Area shall be posted with the appropriate sign. Examples:



Unattended Laser in Operation, Class 3B or Class 4 must be identified with warning sign when the exterior boundry of a non-interlocked laser use area that contains unattended open beams is in operation. Temporary Laser Controlled Areas for Class 3B and Class 4 laser systems must have appropriate NOTICE signs. Examples:



A warning sign must be posted near the entrance to any area that contains a Class 3B or Class4 laser. The sign and the wording must be commensurate with the highest-class laser contained within the area. Laser controlled areas must be indicated with the appropriate warning signs. The term “proper warning indication” generally means that an illuminated warning sign is outside of the area. The light should be flashing and lit only when the laser is on. When a Class 3B or Class 4 laser is left unattended, the door shall always be locked. Non-English-speaking personnel who may need to enter areas where lasers are used must be given appropriate instruction as to the meaning of the warning signs and labels.

Control Measures: Special Considerations and Warning Signs	Classification						
	1	1M	2	2M	3R	3B	4
Laser Optical Fiber Transmission Systems (4.5.2)	MPE	MPE	MPE	MPE	MPE	X	X
Laser Robotic Automated Installations (4.5.3)	—	—	—	—	—	X NHZ	X NHZ
Laser Controlled Area Warning Signs (4.6)	—	—	—	—	—	X	X

LEGEND:
X Shall
— No requirement
MPE Shall if MPE is exceeded
NHZ Nominal Hazard Zone analysis required

(Table from ANSI Z136.1-2014)

1. Equipment Label

All lasers or laser systems (except Class 1) must have appropriate warning labels affixed to a conspicuous place on both the housing and the control panel, in accordance with the Federal Laser Product Performance Standard

Class 2 lasers and laser systems will be labeled, “Laser Radiation – Do Not Stare into Beam”.

Class 3R lasers and laser systems (accessible irradiance does not exceed MPE based upon 0.25 second exposure for wavelengths between 0.4 and 0.7 um), “Laser Radiation – Do Not Stare into Beam or View Directly with Optical Instruments”. All other Class 3a lasers or laser systems, “Laser Radiation – Avoid Direct Eye Exposure”

Class 3b lasers or laser systems will be labeled, “Laser Radiation – Avoid Direct Exposure to Beam”

Class 4 lasers or laser systems will be labeled, “Laser Radiation – Avoid Eye or Skin Exposure to Direct or Scattered Radiation”

J. Training

All laser operators must complete the following prior to becoming an authorized laser user:

1. Initial Laser Safety Training
2. Read all relevant SOP’s
3. Read manufacturer supplied safety documents for relevant laser systems
4. Receive individual instruction on the laser systems to be used by the PI or authorized designee

K. Eye and Skin Hazards

The major risk to laser users is damage to the eye from exposure to a laser beam. The level of damage depends on the wavelength and power of the beam, as well as factors of beam divergence and diameter and the exposure duration. For pulsed lasers, additional parameters include pulse duration and repetition frequency.

1. Eyes

Class 3B and Class 4 lasers can cause immediate, irreparable damage to the retina from thermal burns, acoustic

damage from laser pulses, and photochemical damage.
The cornea and conjunctiva around the eye can also be permanently damaged by lasers, whether immediately through thermal burns or over many years through the development of cataracts.

2. Skin

The hands, arms, and head are the three areas most likely to accidentally come in contact with a laser beam. High powered laser beams can cause thermal, acoustic, and photochemical damage to the skin.

L. Non-Beam Hazards

Non-beam hazards often exist in laser-related operations and can pose significant health and safety risks. Non-beam hazards must be adequately addressed in SOPs where applicable. See Appendix V for a list of non-beam hazards in the laser laboratory.

M. Laser Acquisition, Transfer and Disposal

1. Acquisition

Researchers are to notify the LSO when planning to purchase, fabricate, or otherwise attain a Class 3B or Class 4 laser system. The LSO and PI will review the proposed operation and develop safety requirements prior to installation.

2. Transfer

Lasers may not be transferred to individuals who are not authorized laser users. When transferring any Class 3B or Class 4 laser on campus, contact the LSO to review the process and ensure adequate safeguards are in place.

3. Disposal

All lasers and laser systems must be made inoperative prior to disposal. In addition, the laser system should be evaluated for hazardous components that may require special handling or disposal. Contact the LSO to review.

N. Laser Accidents

1. Emergency Response

If an individual is injured by a laser:

- Shut down power to the laser.
- If the injury is serious or life threatening, call 911.
- If the injury is not serious or life threatening, escort the injured person to student health for treatment.
- All accidents/exposures are to be reported to supervisor as soon as possible.
- The supervisor will immediately notify the LSO.

2. Accident Investigation

Upon notification of an accident, LSO will investigate. Steps of the investigation include:

1. LSO interviews injured workers and witnesses
2. LSO examines workplace for factors associated with the accident/exposure
3. LSO determines the possible causes of the accident/exposure
4. Supervisor takes corrective action to prevent the accident/exposure from recurring
5. Supervisor records the findings and corrective actions taken

Appendix I

LASER REGISTRATION FORM

A. Laser Supervisor / Department Information

Laser Supervisor:	ID/800#:
Phone:	Email:
Building:	Room:
College:	Department:

B. Laser Safety Contacts

Contact:	Name:	Email:	Phone:
Laser Safety Contact			
Laser Safety Officer	Brian Stewart	dstew34@uncc.edu	704-687-1111
Emergency	Campus Police		704-687-2200 or 911

C. Laser / Laser System Parameters

Laser Manufacturer	**Model**	**Serial Number**
Laser Type (CW, Single or Continuous Pulsed)	**Beam Diameter (mm)**	**Beam Divergence (mrad)**

Wavelength(s):_____ ___ um, ___ nm Wavelength(s):_____ ___ um, ___ nm Wavelength(s):_____ ___ um, ___ nm Wavelength(s):_____ ___ um, ___ nm	Max. Beam Power/Energy: _____ __ mW __ mJ Max. Beam Power/Energy: _____ __ mW __ mJ Max. Beam Power/Energy: _____ __ mW __ mJ Max. Beam Power/Energy: _____ __ mW __ mJ

Repetition Rate (Hz):	Radiant Energy (J/pulse):	
Pulse Width(s):	Medium (Argon, Nd:YAG, ETC.):	
Hazard class of laser as indicated by manufacturer: 1__ 2 __ 2a __ 3a __ 3B __ 4 __ Unknown __	Has laser been modified and hazard class changed? ___ Yes ___ No ___ Don't know	
Laser Location/Building:	Room #:	Lab Phone #:

D. Laser Use Description

E. Laser Alignment / Setup Procedure SOP (Description)

Laser Specific Training:

The primary responsibility for ensuring the safe use of the above laser / laser system resides with the Laser Supervisor and individual user(s) associated with the above laser / laser system. Signature indicates the acceptance of this responsibility and conformance to the requirements outlined in the UNC Charlotte Laser Safety Program.

It is the responsibility of the laser supervisor to provide laser specific training and review the UNC Charlotte laser safety manual with laser users prior to operation of any Class 3B or Class 4 laser systems. Please complete this training log and keep a copy with the UNC Charlotte laser safety manual. These documents must be readily available during inspections.

Laser Supervisor Name:	Laser Supervisor Signature:	Date:

Laser User Name:	Laser User Signature:	Date:

Appendix II

Laser Hazard Assessment

It is the goal of Environmental Health and Safety (EHS) to work cooperatively with Principal Investigators and laboratory workers to achieve compliance with University safety policies and governmental regulations. Deficient items and laser safety violations will be handled following the steps outlined in Environmental Health and Safety Policy #703. Issues that represent an immediate or imminent hazard to University Personnel, risk to the environment or potential to cause damage to University facilities are classified at Major Deficiencies (MD) and must be rectified immediately.

LASER PI INFORMATION	
PI:	Date:
Representative:	Department:
Inspector(s):	Building / Room #:

GENERAL	YES	NO	N/A	COMMENT
Is there a capability of the laser to injure people?				
Are there personnel who may use or be exposed to laser radiation?				
Is the location in which the laser is used restricted?				
Are there process interaction between the beam and target materials, e.g., rapid oxidation, ionizing radiation or laser generated air contaminants?				
Are there concerns regarding the beam path, its configuration, level of enclosure or factors applied to the beam?				

LASER BEAM PATH	YES	NO	N/A	COMMENT
Is the nominal hazard zone (NHZ) identified?				
Are optical instruments used for viewing the beam? Are NHZ calculated?				
Will the laser be used indoors? If yes, complete evaluation for indoor use.				
Will the laser be used outdoors?				

LASER USE LOCATION	YES	NO	N/A	COMMENT
Unrestricted location				
Restricted location: Access is granted for authorized people and limited for the public through administrative and engineering control measures.				
Controlled location: Access, occupancy, and activities of people within are subject to strict control and supervision. By interference, controlled locations are restricted locations with laser radiation hazards at Class 4 with additional control measures as specific by the laser operator, the LSO and the PI.				

POSSIBLE PERSONNEL EXPOSURE	YES	NO	N/A	COMMENT
Have possible personnel who may be in the vicinity of the laser been identified and completed training?				

Evaluation for laser indoor use

1. Determine and evaluate all possible beam paths and reflections. Include multiple beam paths due to lack of fixed positioning and unintended beam paths due to unstable mounts, bearing wear, vibration, and re-alignment. Do not forget the possibility of back reflections off optics.
2. Check for and contain hazardous stray reflections.
3. Determine the likelihood for operation or maintenance personnel being within the laser-controlled area during operation.
4. Determine whether optical aids, such as eye loupes or hand magnifies, will be used within 10 cm of a highly divergent beam.
5. Determine whether non-beam hazards exist.

Notes

Appendix III

Laser Inspection Form

It is the goal of Environmental Health and Safety (EHS) to work cooperatively with Principal Investigators and laboratory workers to achieve compliance with University safety policies and governmental regulations. Deficient items and laser safety violations will be handled following the steps outlined in Environmental Health and Safety Policy #703. Issues that represent an immediate or imminent hazard to University Personnel, risk to the environment or potential to cause damage to University facilities are classified at Major Deficiencies (MD) and must be rectified immediately.

LASER INSPECTION INFORMATION	
PI:	Date:
Representative:	Department:
Inspector(s):	Building / Room #:

ADMINISTRATIVE	YES	NO	N/A	COMMENT
Are danger or warning door signs posted and coherent?				
Is emergency contact list up-to-date and posted?				
Are entryway safety controls present: Non-defeatable, defeatable or procedural?				
Is the UNC Charlotte laser safety manual available and reviewed with all users?				
Is the laser inventory up to date?				
Are changes in laser acquisitions, transfers and/or disposals documented with LSO?				
Are laser forms up to date, reviewed, signed and available?				
Are beam alignment procedures and standard operating procedures available for all lasers?				
Have users been trained? Are signed training records available? (General from EHS/Percipio and specific from PI for each laser)				
Is beam height not at eye level?				
Are warning labels present on the machine?				

ENGINEERING CONTROLS	YES	NO	N/A	COMMENT
Is the protective housing and interlock secure?				
Is the emergency stop or master switch operational and clearly labeled?				
Are activation warning light/sound functioning?				

Are room windows protected from beam? Are beams not directed toward entry points or windows?				
Are beam stops, barriers and/or attenuators in place for open beams?				
Are optics secured to prevent stray beams?				
Are reflective materials in the laser area?				

PERSONAL PROTECTIVE EQUIPMENT	YES	NO	N/A	COMMENT
Is laser eyewear in good condition, clearly labeled and appropriate for the laser?				
Is proper skin protection available?				

NON-BEAM HAZARDS	YES	NO	N/A	COMMENT
Are electrical hazards identified?				
Is laser generated air contaminants (LGAC) production identified and mitigated?				
Are fire and explosion hazard minimized?				
Are SDSs reviewed for dyes and other chemicals?				
Are compressed gas tanks secure?				

Notes

Appendix IV

Alignment and Other Open Beam Procedures (Class 3B and Class 4 Lasers)

(From American National Standard Z136.8-2021)

Other open beam procedures may include, but are not limited to, experimental laser runs, setting up, testing, and the use of measurement equipment within the laser beam to measure power and energy or other beam parameters, for example, shape, spatial properties, size, and divergence. Alignments shall be done only by those who have completed laser safety and on-the-job training and are aware of any NBH that may arise. In addition, the following actions should be taken:

a) When possible, align the laser with the lowest power setting possible.
b) Exclude unnecessary personnel from the area during alignment.
c) Replace any enclosures or beam blocks removed as part of the alignment process.
d) Ensure all beams and reflections are properly terminated before high-power operations.
e) Locate and block all stray reflections before proceeding to the next optical component or section.
f) Use skin protection for open UV laser beams, for example, lab coat or long sleeve shirt, and face shields.
g) Use a laser-rated beam block to terminate high-power beams down range or the optics being aligned.
h) Whenever possible, use low-power visible lasers for path simulation of higher-power visible or invisible lasers.
i) Post area warning signs during alignment procedures where lasers are normally Class 1 (enclosed).
j) Place beam blocks behind optics, for example, turning mirrors, to terminate beams that might miss mirrors during alignment.
k) Use a shutter or beam block to block high-power beams at their source, except when needed during the alignment process.
l) When aligning laser beams, use beam display devices such as image converter viewers, phosphor cards or cameras to locate beams.
m) Whenever possible, the use of remote viewing devices, for example, CCD image sensors, web cameras, and automated devices that employ motorized mounts and positioning equipment, should be considered.
n) Wear laser eye protection (LEP) whenever that may be an open beam above the MPE as determined in consultation with the LSO. Laser alignment eyewear should be worn with visible lasers.

At times, laser alignment must be done with enough energy when beam (exposure) and NBH (fire) are still significant. In these cases, the use of a two-person rule should be considered.

Appendix V

Non-Beam Hazards

Electrical Hazards

Electrical hazards may be present during installation, maintenance, and service of laser systems. Individuals involved in such procedures must be trained in electrical safety and in proper lockout-tagout procedures.

- Class 3B and 4 lasers should have a separate circuit and local cut-off switch (breaker) for the circuit.
- Label and post electrical high voltage hazards and switches. Clearly identify the main switches to cut-off power.
- Have at least two people in an area while working on high-energy power systems.
- Keep cooling water connections away from main power and high voltage outlets and contacts. Use double hose clamps on cooling water hoses. Inspect cooling water hoses and connections and power cables and connectors periodically as part of a regular equipment inspection.
- No one should work on lasers or power supplies unless qualified and approved to perform the specific tasks
- Do not wear rings, watches or other metallic apparel when working with electrical equipment
- Do not handle electrical equipment when hands or feet are wet or when standing on a wet surface
- When working with high voltages, regard all floors as conductive and grounded
- Be familiar with electrocution rescue procedures and emergency first aid
- Prior to working with electrical equipment, de-energize the power source and “lock-out tag-out” the disconnect switch
- Check that each capacitor is discharged, shorted, and grounded prior to working in the area of the capacitors
- When possible, use shock preventing shields, power supply enclosures and shielded leads in all experimental or temporary high voltage circuits

Laser-Generated Air Contaminants

Laser-Generated Air Contaminants (LGACs) may be generated when certain Class 3B and Class 4 lasers beams interact with matter. Characteristics of the contaminants depend upon the target material, cover gas, and beam irradiance.

Collateral and Plasma Radiation

Refers to radiation produced by system components other than the primary laser beam. The LSO will coordinate with various departments within EH&S to ensure proper evaluation and recommendation of appropriate controls, if necessary.

Radiation (Ionizing Radiation)

X-rays may be produced from electrical components of laser systems greater than 15 kV and from laser-metal induced plasmas.

Ultraviolet (UV) and Visible Radiation

Laser discharge tubes and pump lamps may generate UV and visible radiation. Levels produced may cause skin and eye damage.

Plasma Radiation

Interactions between very high-power laser beams and target materials may produce plasma radiation (the complete dissociation of nuclei and orbital electrons). The plasma generated may contain hazardous "blue light" and UV emissions which can be an eye and/or skin hazard. When targets are heated to very high temperatures

(e.g., laser welding and cutting) an intense light is emitted. This light often contains large amounts of short wavelength, or blue light, which may cause conjunctivitis, photochemical damage to the retina or erythema (sunburn-like reactions) to the skin.

Fire Hazards

Class 4 laser beams represent a fire hazard and under some situations it is possible that Class 3 lasers can initiate fires. Use flame retardant materials wherever applicable with all laser applications. Opaque laser barriers (curtains) normally cannot withstand high powered beam exposure for more than a few seconds without some damage, (smoke, open fire, or penetration). Class 4 laser operators should also be aware of unprotected wire insulation and plastic tubing that may catch on fire from intense reflected or scattered beams, particularly from lasers operating at invisible wavelengths.

Explosion Hazards

High-pressure arc lamps, filament lamps, and capacitor banks in laser equipment can explode if they fail. These must be enclosed in housings which can withstand the maximum explosive pressure resulting from component disintegration.

Compressed Gases

Individuals using compressed gases must first complete training on safe use and application. An SOP needs to be developed for the safe handling of gases, and should include information on cylinder restraints, use of regulators, relief valve settings, and proper tubing and fittings.

Chemicals

Laser dyes are complex fluorescent organic compounds. Certain dyes are highly toxic or carcinogenic. Chemical users must be familiar with the UNCC Chemical Hygiene Plan. In addition, chemical users shall obtain and review the Safety Data Sheet for each dye prior to use.

Cryogenic Liquids

Liquid nitrogen may be used to cool certain lasers. Evaporating liquid nitrogen can displace atmospheric oxygen and create an oxygen deficient atmosphere, leading to asphyxiation. In addition, the extremely cold temperature of liquid nitrogen can cause eye and skin damage and frostbite. Gloves made specifically for handling cryogenics are to be worn when using liquid nitrogen.