

Wake Forest University

# Laser Safety Plan

## Contents

<b>A. Scope</b>	5
B. Laser Safety Program	5
C. Responsible Parties	5
1. Laser Safety Officer (LSO)	5
2. Departments	5
3. Laser User:	6
D. Hazard Classification	6
1. Laser System Classes, Hazards and Requirements	6
E. Control Measures	7
1. General Control Considerations	7
F. Administrative Controls	8
1. Standard Operating Procedures	8
2. Training	8
3. Authorized Personnel	8
4. Indoor Laser Control Area (LCA)	8
a. The Class 3B and Class 4 LCA shall:	8
b. The Class 3B and Class 4 LCA should:	8
c. Class 4 LCA shall:	8
5. Temporary Laser Controlled Area – TLCA	9
6. Outdoor Control Measures	9
7. Laser in Navigable Airspace	9
8. Alignment and Open Beam Procedures	10
9. Beam Height	10
10. Visitors and Spectators	10
11. Service Personnel	10
G. Engineering Controls	11
1. Protective Housing	11
2. Safety Interlocks and Service Panels	12

3. Master Switch Controlled Access	12
4. Windows, Diffuse Display Screens, Collecting Optics	12
5. Beam Paths	12
a. Beam Stops	12
b. Open Beam Paths	12
c. Enclosed Beam Path	12
6. Activation Warning and Emission Delay	12
7. Controlled Areas	13
8. Entryway Controls	13
a. Non-defeatable entryway	13
b. Defeatable Entryway	13
c. Procedural Entryway Controls	13
9. Protective Barriers and Curtains	13
H. Personal Protective Equipment	14
1. Protective Eyewear	14
a. Labeling of Protective Eyewear	15
b. Care and Maintenance	15
c. Inspection	15
2. Skin Protection	15
I. Warning Signs and Labels	16
1. Equipment Label	17
J. Training	18
K. Eye and Skin Hazards	18
1. Eyes	18
2. Skin	18
L. Non-Beam Hazards	18
M. Laser Acquisition, Transfer and Disposal	18
1. Acquisition	18
2. Transfer	18
3. Disposal	19

N. Laser Accidents	19
1. Emergency Response	19
2. Accident Investigation	19
Appendix I	20
Appendix II	22
Appendix III	24
Appendix IV	26
Appendix V	28
Electrical Hazards	29
Laser-Generated Air Contaminants	29
Collateral and Plasma Radiation	29
Radiation (Ionizing Radiation)	29
Ultraviolet (UV) and Visible Radiation	29
Plasma Radiation	29
Fire Hazards	30
Explosion Hazards	30
Compressed Gases	30
Chemicals	30
Cryogenic Liquids	30

## A. Scope

Wake Forest University (WFU) requires that all lasers and laser systems be operated in accordance with the American National Standards Institute (ANSI) Z136.1 – 2007, “American National Standard for Safe Use of Lasers” and ANSI Z136.8 – 2012, “American National Standard for Safe Use of Lasers in Research, Development, or Testing”, as well as other applicable federal and state regulations. ANSI Z136.8 standard provides recommendations for the safe use of lasers with wavelengths between 180nm and 1000 um.

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. ANSI Z136.1 sets forth the current hazard classifications.

## B. Laser Safety Program

WFU has the responsibility to provide a safe working environment to 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) 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 necessary steps 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. Provide protective measures – including warning signs and labels, PPE guidance, administrative and engineering controls.
- iii. Periodically audit lasers use facilities.
- iv. Investigate laser accidents and implement plans and procedures to prevent recurrences.
- v. Maintain inventory of Class 3b and Class 4 lasers and laser systems.

A Deputy Laser Safety Officer (DLSO) 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. Identify laser hazards present in the work area, 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 SOP (Appendix II)** as a guide.
- iv. Identify all authorized personnel who are eligible to operate or maintain a Class 3b or Class 4 laser or laser system.
- v. Ensure training is provided to each laser user (to include the physical hazards, health hazards, and emergency procedures).
- vi. Conduct annual self-inspection of lasers and laser use area using the **Laser Safety Self-Evaluation Form (Appendix III)**.
- 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, training, 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 a number of 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 is 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 hazards 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.

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 EXPOSURE	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 dose range.	Can instantly burn skin. Avoid direct exposure to beam.
Material burn hazard	None		None		None	Can burn materials if beam contacts substance at dose 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 <sup>b</sup>	Required	Not required <sup>b</sup>	Required	Required
Training	Not required	Application Dependent <sup>a</sup>	Not required <sup>b</sup>	Application Dependent <sup>a</sup>	Not required <sup>b</sup>	Required	Required
LSO	Not required	Application Dependent <sup>a</sup>	Not required	Application Dependent <sup>a</sup>	Not required <sup>b</sup>	Required	Required
Engineering Controls	Not required	Application Dependent <sup>a</sup>	Not required <sup>b</sup>	Application Dependent <sup>a</sup>	Not required <sup>b</sup>	Required	Required

<sup>a</sup> 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

<sup>b</sup> 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 are 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.

### 3. Authorized Personnel

Authorized personnel only 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 also 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. Employ beam stops to stop hazardous beams.
4. Provide appropriate eye protection
5. Ensure exposed beam is above or below eye level of standing or sitting personnel.
6. Keep LCA illuminated as bright as practicable in order to constrict eye pupils.
7. Cover or restrict windows, doorways, portals to reduce the transmitted laser radiation to levels at or below MPE.
8. Prevent unauthorized and/or unattended use.

#### *c. Class 4 LCA shall:*

Provide entryway safety controls designed to allow both rapid egress by laser personnel at all times 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 clearly evident 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 beam 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.
- l. 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

1301 S. Terminal Service Road  
Greensboro, NC 27409  
(336) 369-3900

Additionally, laser light show 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 IV

## 9. Beam Height

Beam height should be set at a level that is not the normal position of the eye of an individual in 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 of 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, a 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 LSO whenever a Class 3B or Class 4 laser will be 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.

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 to the 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 alternate set of controls approved by the LSO in order 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

A blocking barrier or curtain can be used to block or filter laser beams 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 to 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 Z87.1-1989.

Even when the accessible radiation levels are considered safe, it is good practice for personnel to wear eye protection at all times 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 the optical density and wavelength. Color-coding or other distinctive identification is recommended in multi-laser environments.

#### *b. Care and Maintenance*

The 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.).

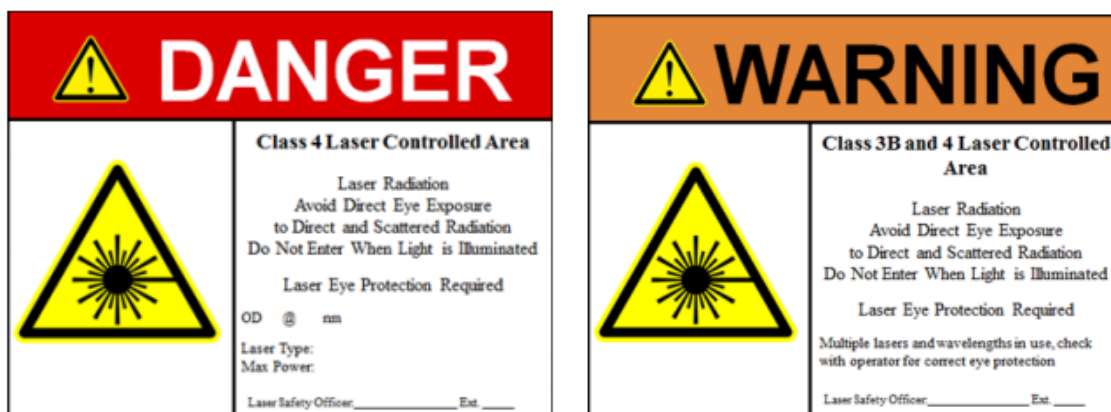
Personal Protective Equipment PPE	Classification						
	1	1M	2	2M	3R	3B	4
Laser Eye Protection (4.4.4.1)	—	—	—	—	—	X	X
Skin Protection (4.4.4.3)	—	—	—	—	—	•	•
Protective Clothing (4.4.4.1 and 4.4.4.3.1)	—	—	—	—	—	•	•

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 boundary of a non-interlocked laser use area that contains unattended open beams is in operation. Example:





Temporary Laser Controlled Areas for Class 3B and Class 4 laser systems must have appropriate NOTICE signs.  
Example:



A warning sign must be posted near the entrance to any area that contains a Class 3B or Class 4 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  $\mu\text{m}$ ), “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 SOPs
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

<b>A. (Laser Supervisor) / Department Information</b>			
Laser Supervisor:		ID:	
Phone:		Email:	
Building:		Room:	
Department:		PI:	
<b>B. Laser / Laser System Parameters</b>			
<b>Laser Manufacturer</b>		<b>Model</b>	
<b>Serial Number</b>			
<b>Laser Type(CW, Pulsed,qSwitched)</b>		<b>Beam Diameter (mm)</b>	
		<b>Beam Divergence (mrad)</b>	
Wavelength(s): _____ um, _____ nm		Max. Beam Power/Energy: _____ mW _____ mJ	
Wavelength(s): _____ um, _____ nm		Max. Beam Power/Energy: _____ mW _____ mJ	
Wavelength(s): _____ um, _____ nm		Max. Beam Power/Energy: _____ mW _____ mJ	
Wavelength(s): _____ um, _____ nm		Max. Beam Power/Energy: _____ mW _____ mJ	
Repetition Rate (Hz):		Radiant Energy (J/pulse):	
Pulse Width:		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 #:
<b>C. Laser Use Description</b>			
<b>LS Name:</b>		<b>Signature:</b>	
<b>Date:</b>			

**Note:**

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 WFU Laser Safety Program.

## Appendix II

## LASER SOP FORM

### A. Laser Safety Contacts

Contact:	Name:	Phone:	Mobile:
Laser Supervisor:			
Primary Laser User			
EHS / LSO		336-391-3427	
Emergency	Campus Police	704-391-5911 or 911	

### B. Laser / Laser System Parameters (from Laser Registration)

Laser Manufacturer	Model	Serial Number
Laser Type(CW, Pulsed,qSwitched)	Beam Diameter (mm)	Beam Divergence (mrad)
Wavelength(s): _____ um, _____ nm	Max. Beam Power/Energy: _____ mW _____ mJ	
Wavelength(s): _____ um, _____ nm	Max. Beam Power/Energy: _____ mW _____ mJ	
Wavelength(s): _____ um, _____ nm	Max. Beam Power/Energy: _____ mW _____ mJ	
Wavelength(s): _____ um, _____ nm	Max. Beam Power/Energy: _____ mW _____ mJ	
Repetition Rate (Hz):	Radiant Energy (J/pulse):	
Pulse Width:	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 #:

### C. Brief Description of laser use

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### D. Laser Alignment / Setup Procedure (Description)

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# Appendix III



Laser Safety Checklist					
PI:					
Date:					
Location:					
Item	Engineering Controls	Satisfactory	Unsatisfactory	NA	Comments
1	Optics secured to prevent stray beams				
2	Laser path not at eye level				
3	Open beam protections in place				
4	Beam stops/Barriers/ Attenuators in place				
5	Protective housing and interlock secure				
6	Emergency stop / Master switch operational				
7	Activation warning (light/sound) functioning				
8	Room windows protected from beam				
9	Reflective materials not in beam path				
<b>Administrative Controls</b>					
10	Users have been trained				
11	SOP up-to-date, reviewed by users, and signed				
12	SOP readily available in room				
13	Laser Controlled Area identified and marked				
14	Warning labels on machine present				
15	Door signs posted and coherent				
16	Beam alignment procedure available				
17	Beam not directed toward entry points or window				
18	Laser safety guidelines posted				
19	Laser safety manual available, reviewed				
20	Emergency contact list up-to-date and posted				
<b>Personal Protective Equipment</b>					
21	Proper PPE available - eyewear, lab coat				
22	Laser eyewear appropriate for the laser				
23	Laser eyewear in good condition				
24	Proper skin protection available				
25	Barriers or curtains present				
<b>Non-Beam Hazards</b>					
26	Electrical hazards identified				
27	Fire and explosion hazard minimized				
28	Compressed gas tanks secure				
29	SDS reviewed for dyes and other chemicals				
30	LGAC production identified and mitigated				
Inspection Completed By:					

# Appendix IV

## Alignment and Other Open Beam Procedures for Class 3B and Class 4 Lasers

(from American National Standard Z136.8-2012)

- a) Exclude unnecessary personnel from the area during alignment.
- b) Wherever possible, use low-power visible lasers for path simulation of higher power visible or invisible lasers.
- c) Wear protective eyewear and clothing
  - 1. Laser alignment eyewear with visible lasers
  - 2. Lab coat or long sleeve shirt with UV lasers
- d) When aligning invisible (and some visible) laser beams, use beam display devices such as image convertor viewers to locate the beam.
- e) Whenever possible use remote viewing or automated viewing devices.
- f) Perform high power alignments at the lowest possible power.
- g) Use a beam block or shutter to block high power beams at the source except when actually needed during the alignment process.
- h) Use a laser-rated beam block to terminate high power beams down range of the optics under alignment.
- i) Use beam blocks or barriers when alignment beams could stray from the area.
- j) Place beam blocks behind optics to terminate beams that might miss mirrors during alignment.
- k) Locate and block all stray reflections before proceeding to the next section.
- l) Be sure all beams and reflections are properly terminated before high power operation.
- m) Post warning signs during alignment where Class I lasers are normally enclosed.
- n) Replace any enclosures or beam blocks removed as part of the alignment process

# 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 persons 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 (example, 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 WFU 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.