AUGUSTA UNIVERSITY

Laser Safety Guide

September 23rd, 2016

Environmental Health and Safety Division

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AUGUSTA UNIVERSITY

Laser Safety Program Policy

The primary objective of the Augusta University (AU) laser safety program is to ensure that no laser radiation in excess of the maximum permissible exposure (MPE) limit reaches the human eye or skin. Additionally, the program is designed to ensure that adequate protection against collateral hazards is provided. These collateral hazards include, but are not limited to, the risk of electrical shock, fire hazard from a beam or from use of dyes and solvents, chemical exposure from use of chemicals and vaporization of targets, and the emission of ionizing and non-ionizing radiation from power supplies associated with the operation of the laser or laser system.

To achieve this objective, AU requires that all Class 3B and Class 4 lasers and laser systems operate in accordance with the American National Standards Institute (ANSI) Z136.1-2014 Safe Use of Lasers, ANSI Z136.5-2009 Safe Use of Lasers in Educational Institutions, ANSI Z136.3-2011 Safe Use of Lasers in Health Care, ANSI Z136.8-2012 Safe Use of Lasers in Research, Development, or Testing, and applicable federal and state regulations. As such, AU adopts ANSI Z136.1-2014, ANSI Z136.5-2009, ANSI Z136.3-2011, and ANSI Z136.8-2012 as the basis of its laser safety program.

A Laser Safety Subcommittee (LSS) has been established to provide oversight and policy guidance of the laser safety program. Additionally, the LSS assists in the education and approval of laser users.

The Laser Safety Officer (LSO) has the authority to suspend, restrict, or terminate the operation of a laser system if it is deemed that laser hazard controls are inadequate or the method of operation presents a threat to human health, property, or the environment. This authority is granted by the President of AU. All Class 3B and Class 4 lasers at AU shall be registered with the LSO and the LSS. The LSO will register these systems with the Georgia Department of Community Health. The LSO will conduct a laser hazard assessment and it will be the responsibility of the Principal Laser User (PLU) to correct any safety deficiencies identified in the hazard assessment. This laser safety program applies to all AU locations, including mobile and temporary field locations.

1.0 Introduction.

The primary objective of the AU Laser Safety Program is to ensure the safe use of laser radiation and to minimize the risk of laser radiation in excess of the maximum permissible exposure (MPE) limit reaching the eyes or skin. Additionally, the program is designed to ensure that adequate protection against collateral hazards is provided (collateral hazards are described in 5.0 Laser System Hazards). See Laser Safety Program Policy.

This guide summarizes the requirements and responsibilities of laser users at Augusta University (AU). The Laser Safety Guide is available online at Environmental Health and Safety's website at http://www.augusta.edu/services/ehs/lasersafetyoff/. Laser users are required to familiarize themselves with the provisions of this guide.

AU uses laser systems in education, research, and patient care. The Laser Safety Subcommittee (LSS) designates staff or faculty members as Principal Laser Users (PLU) after a review of proposed use, adequacy of facilities and training of the applicant. Adequacy of facilities is determined by the LSO in accordance with Appendix D: Inspection Checklist

To achieve this objective, AU requires that all Class 3B and Class 4 lasers and laser systems operate in accordance with the American National Standards Institute (ANSI) Z136.1-2014 Safe Use of Lasers, ANSI Z136.5-2009 Safe Use of Lasers in Educational Institutions, ANSI Z136.3-2011 Safe Use of Lasers in Health Care, ANSI Z136.8-2012 Safe Use of Lasers in Research, Development, or Testing, and applicable federal and state regulations. The Laser Safety Program applies to all AU locations, including off-campus, mobile and temporary locations. Links to state and federal regulations are as follows:

Georgia Rule 290-5-27-.02 http://rules.sos.state.ga.us
Go to Department of Human Resources Chapter 290-5-27-02 (Laser Radiation)

OSHA Technical Manual http://www.osha.gov/dts/osta/otm/otm_iii/otm_iii_6.html

2.0 Responsibilities.

2.1 Laser Safety Sub-committee (LSS).

The LSS of the Radiation Safety Committee (RSC) is an oversight body for laser safety at AU. The LSS may withdraw permission for laser use. The LSS is responsible for:

2.1.1 Ensuring that AU procedures, safety guides, and training for laser devices are implemented according to accepted safety practices.

2.1.2 Ensuring that only qualified individuals are permitted to use laser devices.

2.1.3 Reviewing reports from the Laser Safety Officer (LSO) summarizing annual laser inspections, including compliance with safety related engineering and administrative controls and use of personal protective equipment, occupational exposure for all personnel, and compliance with Federal/State of Georgia regulations.

2.1.4 Enforcing compliance with the program, including withdrawal of permission to use lasers.

2.1.5 Providing advice, guidance and support to research groups, departments and investigators via the LSO.

2.1.6 Advising on the need for medical surveillance following accidental exposure.

2.1.7 Tracking corrective actions for items of concern identified by the LSO or the LSS.

2.2 Laser Safety Officer (LSO).

The LSO is responsible for the day to day administration and implementation of the procedures that support safety and compliance in the Laser Safety Program. The LSO shall be qualified by completion of recognized industry training and shall be approved by the LSS. The LSO is responsible for:

2.2.1 Reviewing requisitions for laser systems prior to purchase to ensure that the purchaser is included in the laser safety program.

2.2.2 Classifying lasers and laser systems.

2.2.3 Conducting hazard evaluations of laser work areas, including the establishment of Nominal Hazard Zones (NHZ).

2.2.4 Ensuring that the prescribed control measures are implemented and maintained. This includes recommending or approving substitute or alternate control measures when the primary ones are not feasible or practical.

2.2.5 Reviewing Class 3B and Class 4 standard operating procedures.

2.2.6 Recommending and approving protective equipment including eyewear, clothing, barriers, screens, etc., as may be required to assure personnel safety.

2.2.7 Ensuring that correct warning signs and labels are posted.

2.2.8 Review and approval for new or modified Class 3B and Class 4 laser facilities prior to use.

2.2.9 Assuring that laser use areas and laser equipment are audited annually to assure proper operation.

2.2.10 Providing laser safety education and training, including refresher training, is provided for laser personnel involved in the use of lasers.

2.2.11 Maintaining laser safety program records.

2.2.12 Maintaining an Emergency Response Plan for actual or suspected exposure to potentially harmful laser radiation. See Appendix H: Laser Accident Response Plan Template

2.2.13 Submitting bi-annual reports to the LSS detailing the status of the Laser Safety Program.

2.3 Principal Laser User (PLU).

The PLU shall be knowledgeable of the requirements for laser safety; the potential hazards and associated control measures for laser systems; and policies, practices and procedures pertaining to lasers under their authority. The PLU is responsible for:

2.3.1 Instructing and training on laser hazards and safety controls for Laser Users under his/her authority.

2.3.2 Supervising Laser Users under his/her authority to ensure safe operation of laser systems.

2.3.3 Ensuring adequate control of hazards to employees, students, visitors, and the general public prior to allowing the laser to be used.

2.3.4 Ensuring that individuals scheduled to work with lasers are listed on Laser Registration Forms. (See Appendix C: Laser System Registration Form)

2.3.5 Purchasing laser safety personal protective equipment and devices.

2.3.6 Ensuring that sufficient protective eyewear of the correct optical density is readily available, in good condition, and worn during laser setup and operation.

2.3.7 Implementing the laser accident response plan for known or suspected laser exposures. See Appendix H: Laser Accident Response Plan Template.

2.3.8 Reporting all laser accidents or injuries to the LSO immediately.

2.3.9 Submitting plans for new or modified Class 3B and Class 4 laser installations to the LSO for review and transmittal to the Laser Safety Sub-Committee.

2.3.10 Obtaining LSO approval before placing Class 3B or Class 4 lasers into operation.

2.3.11 Notifying the LSO when decommissioning, transferring or disposing of lasers or laser systems.

2.3.12 Obtaining a baseline optical exam for laser workers before they begin work with Class 3B and Class 4 lasers if required by the Laser Safety Sub-Committee.

2.3.13 Developing written laser specific SOPs for Class 3B and Class 4 lasers and laser systems. The SOPs shall include instructions for operation, maintenance, and other relevant safety considerations. (See Appendix G: Standard Operating Procedure Template).

2.3.14 Enforcing the safety requirements prescribed in this guide.

2.3.15 Laser accident responsibilities.

2.3.15.1 Assist the affected worker in obtaining medical support.

2.3.15.2 Stop work using the laser system and preserve the incident scene for investigation.

2.3.15.3 Notify the Laser Safety Officer (or the on-call EHS staff member) as soon as possible.

2.3.16 Retaining laser safety-related records including Standard Operating Procedures, inspection reports, operating manuals, and vendor specifications shall be retained for a minimum of one year beyond termination of use.

2.4 Laser Users.

Laser Users operate laser systems under the supervision of the PLU. Laser Users are responsible for:

2.4.1 Reading and complying with this guide.

2.4.2 Completing laser safety training provided by the LSO prior to starting work with lasers.

2.4.3 Obtaining a baseline optical exam before starting work with lasers, if required by the Laser Safety Subcommittee (LSS).

2.4.4 Not using a laser or working within a laser's nominal hazard zone unless authorized by the PLU.

2.4.5 Complying with safety rules, procedures, and instructions prescribed by the PLU and the LSO, to include wearing the appropriate protective eyewear.

2.4.6 Understanding laser operating procedures.

2.4.7 Restricting access of ancillary services personnel into a room or area where a Class 3B or Class 4 laser is operating.

2.4.8 Reporting all laser accidents or injuries to the PLU and the LSO.

2.4.9 Obtaining written PLU approval before deviating from the SOP.

3.0 Laser System Classification.

Lasers produce intense, coherent beams of electromagnetic radiation. Interaction with the human body is generally at the surface, affecting the eye and the skin. Laser classification is related to the potential for biological injury resulting from exposure to the eye (by direct viewing or viewing through a lens), or exposure to the skin. Laser devices can be classified into 7 different classes – Class 1, 1M, 2, 2M, 3R, 3B, and 4 based on the ability of the laser beam to cause biological damage to the eye of skin during use.

3.1 Class 1 Laser Systems.

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

Any laser, or laser system containing a higher Class laser, that cannot emit accessible laser radiation levels during operation in excess of the applicable Class 1 accessible emission level (AEL) for any duration within the maximum duration (30,000 s, except for infrared system where 100 s shall be used) inherent in the design or intended use of the laser or laser system

Note – A common example of a Class I laser system is one that includes an embedded higher class laser, but during normal operation presents no laser radiation hazard to the user.

3.2 Class 1M Laser Systems.

- 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 of than to prevent potentially hazardous optically aided viewing.

Any laser, or laser system that cannot emit during operation accessible laser radiation levels in excess of the applicable Class 1 AEL under the conditions of measurement for the unaided eye, but exceeds the Class 1 AEL for telescopic viewing and does not exceed the Class 3B AEL, for any emission duration within the maximum duration (30,000 s) inherent in the design or intended use of the laser or laser system. The maximum exposure duration is assumed to be no more than 30,000s.

3.3 Class 2 Laser Systems

- Emits in the visible portion of the spectrum (400nm to 700nm) and
- Eye protection is normally afforded by the aversion response for unaided viewing.

Class 2 lasers or laser systems are visible (400nm – 700nm) CW and repetitive-pulse lasers and laser systems that can emit accessible radiant energy exceeding the appropriate Class 1 AEL for the maximum duration inherent in the design or intended use of the laser or laser system, but not exceeding the Class 1 AEL or any applicable pulse (emission) duration < 0.25s. The Class 2 AEL is based on the MPE for a 0.25s exposure duration for a visible laser.

3.4 Class 2M Laser Systems.

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

Any laser or laser system that is a visible (400nm – 700nm) CW or repetitive-pulsed lasers or laser systems that cannot emit during operation accessible laser radiation levels in excess of the applicable Class 2 AEL under the conditions of measurement for the unaided eye, but exceeds the Class 2 AEL for telescopic viewing and does not exceed the Class 3B AEL, for any emission duration within the maximum duration (0.25 s) inherent in the design or intended use of the laser or laser system.

3.5 Class 3R Laser Systems

- Has reduced control requirements and
- Is potentially hazardous under some direct and specular 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 3R lasers and laser systems include those that have an accessible output between 1 and 5 times the Class 1 AEL for wavelengths shorter than 400nm or longer than 700nm, or less than 5 times the Class 2 AEL for wavelengths between 400nm and

700nm. The Class 3R AEL is defined as 5 times the class 1 AEL for invisible lasers and 5 times the Class 2 AEL for visible lases (λ between 400nm and 700nm).

3.6 Class 3B Laser Systems.

- 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 contaminant (LGAC) production hazard.

Class 3B lasers and laser systems include:

a) Lasers and laser systems operating outside the retinal hazard region (i.e., < 400nm or > 1400nm) that can emit accessible radiant power in excess of the Class 3R AEL during any emission duration within the maximum duration inherent in the design of the laser or laser system, but which (a) cannot emit an accessible average radiant power in excess of 0.5W for $T \geq 0.25$s or (b) cannot produce accessible radiant energy greater than 0.12J within an exposure duration $T < 0.25$s.

b) Visible (400nm to 700nm) and near infrared (700nm to 400nm) lasers and laser systems that emit in excess of the AEL of Class 3R but which (a) cannot emit an accessible average radiant power in excess of 0.5W for $T \geq 0.06\ C_A$ J s and (b) cannot emit an accessible radiant energy greater than $0.04\ C_A$ J per pulse for $t <$ 0.06 CA s when 0.5W peak power is exceeded. In addition, the per pulse accessible radiant energy shall not exceed 0.125J. For this limit, pulses separated by less than t_{min} are considered to be one pulse.

3.7 Class 4 Laser Systems.

- Is a hazard to the eye or skin from direct beam,
- May pose a fire hazard or diffuse reflection hazard, and
- May also produce laser generated air contaminants (LGAC) and hazardous plasma radiation.

Class 4 lasers and laser systems are those that emit accessible laser radiation that exceeds the Class 3B AEL.

3.8 Embedded Laser Systems.

Class 2, 3, or 4 lasers contained in a protective housing and operated in a lower classification mode may be reclassified downward. Specific control measures are required to maintain the lower classification. Approval of the LSO is required for reclassification of embedded systems that are non-commercial design and construction.

4.0 Laser System Acquisition, Transfer, and Disposal

Are done in accordance with Georgia Department of Public Health Chapter 270-5-27-02, *Rules and Regulations for Laser Radiation.* See 1.0 for link to web site.

4.1 Laser System Acquisition.

4.1.1 Staff or faculty anticipating purchase of a Class 3B or Class 4 laser system shall coordinate with the LSO in advance of purchase.

4.1.2 The LSO shall review purchase requisitions for Class 3B and Class 4 laser systems.

4.1.3 Upon receipt and prior to use the PLU (or prospective PLU) shall complete the laser system registration form (Appendix C: Laser System Registration Form) and submit it to the LSO.

4.2 Laser System Transfer.

The PLU shall notify the LSO when a Class 3B or Class 4 laser is to be moved within the facility, or is transferred to another PLU prior to being moved. The laser may not be operated in the new location until the LSO completes the laser hazard evaluation and all required controls are in place.

4.3 Laser System Disposal.

The PLU shall notify the LSO when a laser system is no longer used, declared as excess property, or designated for disposal.

5.0 Laser System Hazards

Current lasers emit beams of optical radiation. Optical radiation (ultraviolet, visible, and infrared) is termed non-ionizing radiation to distinguish it from ionizing radiation such as X-rays and gamma rays, which are known to cause different biological effects.

5.1 Eye Hazards.

The major hazard of laser light is eye exposure. The eye is the organ most sensitive to light. Just as a magnifying glass can be used to focus the sun and burn wood, the lens in the human eye focuses the laser beam into a tiny spot that can burn the retina. Corneal or retinal burns (or both), depending upon laser wavelengths are possible from acute exposure with sufficient energies. Corneal, lenticular opacities (cataracts), or retinal injury may be possible from lengthy exposure to excessive levels of ultraviolet radiation due to photochemical effect.

5.2 Skin Hazards.

Lasers can harm the skin via photochemical or thermal burns. Depending on the wavelength, the beam may penetrate both the epidermis and the dermis. The epidermis is the outermost living layer of skin. Far and mid-ultraviolet (the actinic UV) are absorbed by the epidermis. Sunburn (reddening and blistering) may result from short-term exposure to the beam. UV exposure is also associated with an increased risk of developing skin cancer and premature aging (wrinkles, etc.) of the skin.

Thermal burns to the skin are rare. They usually require exposure to high-energy beams for an extended period of time. Carbon dioxide and other infrared lasers are most commonly associated with thermal burns, since this wavelength range penetrates deeply into skin tissue. The resulting burn may be first degree (reddening), second degree (blistering) or third degree (charring).

Some individuals are photosensitive or may be taking prescription drugs that induce photosensitivity. Particular attention must be given to the effect of antibiotics and fungicides when working around lasers. Consult Employee Health and Wellness at (706) 721-3418 when employees report taking these medications.

5.3 Electrical Hazards.

Laser systems can present an electric shock hazard. This may occur from contact with exposed utility power, device control, and power supply conductors operating at potentials of 50 volts and above. These exposures can occur during laser setup or installation, maintenance and service, where equipment protective covers are often removed to allow access to active components as required for those activities. Those exposed can be equipment installers, users, technicians, and uninformed members of the public.

The effect upon those who accidentally come into contact with energized conductors at or above 50 volts can range from a minor “tingle”, to startle reaction, to serious personal injury or death. Electric shock is a very serious hazard, and deaths associated with laser systems have occurred.

5.4 Fire Hazards.

Class 4 laser beams present a fire hazard. Enclosure of Class 4 laser beams can result in potential fire hazards if enclosure materials are likely to be exposed to irradiances exceeding $10W/cm^2$ or beams exceeding 0.5W. Under some conditions where flammable compounds and substances exist, it is possible that fires can be initiated by Class 3B lasers.

NOTE – The National Fire Protection Agency (NFPA) standard 115 states that for CW lasers, $0.5W/cm^2$ is a possible ignition hazard.

Opaque laser barriers (e.g., curtains) can be used to block the laser beam from exiting the work area during certain operation. While these barriers can be designed to offer a range of protection, they normally cannot withstand high irradiance levels for more than a few seconds without some damage (e.g., production of smoke, open fire, or penetration). Users of commercially available laser barriers should obtain appropriate fire prevention information from the manufacturer.

Operators of Class 4 lasers should be aware of the ability of unprotected wire insulation and plastic tubing to catch on fire from intense reflected or scattered beams, particularly from lasers operating at invisible wavelengths. The risk of fire is greater in oxygen-rich atmospheres when oxygen or nitrous oxide is being used.

5.5 Collateral and Plasma Radiation.

Collateral radiation is radiation other than that associated with the primary laser beam and is produced by system components such as power supplies, discharge lamps and plasma tubes. Such radiation may take the form of x-radiation, UV, visible, IR, microwave and radiofrequency (RF) radiation. Plasma radiation is generated when an energetic laser beam interacts with matter, typically metals, when high power pulsed laser beams (peak irradiance of the order of 10^{12} W/cm^{-2}) are focused on a target.

5.6 Laser Generated Airborne Contaminants.

Air contaminants may be generated when certain Class 3B and Class 4 laser beams interact with matter. The quantity, composition, and chemical complexity of the LGAC depend greatly upon target material, cover gas, and the beam irradiance.

In operations using lasers that vaporize tissue through disruption of cells, laser generated airborne contaminants (LGAC) result as an airborne hazard requiring appropriate management. Analysis of these contaminants produced during laser surgical procedures has shown the presence of gaseous toxic compounds, bio-aerosols, cellular material, and viruses.

At certain concentrations, some of the LGAC may cause ocular and upper respiratory tract irritation, have unpleasant odors, create visual problems for the user, and have been shown to have mutagenic and carcinogenic potential. It has been shown that laser smoke production is a function of increased irradiance levels. Therefore, laser surgical procedures requiring high irradiance levels are more likely to produce LGAC.

5.7 Irradiance Dependence of Specific Non-Beam Hazards (NBH)

NBH	Approximate Minimum Irradiance (W/cm^2)	Potential Control Measures
Ignition of easily-ignited materials	1 to 10	Non-combustible barrier materials
LGAV production [a]	10^3 (low Z material) $10^3 – 10^6$ (plastics)	Adequate building ventilation Local exhaust ventilation (LEV)
	$10^6 – 10^7$ (high Z material; composites, metals, tissue)	LEV, respiratory protection (where LEV cannot be implemented or while it is being implemented
Plasma production	~ 10^{12} (metals) ~ 10^{14} (dielectrics)	Limit personnel exposure to plasma radiation
Production of ionizing radiation may approach regulatory exposure limits (occupational)	~ 10^{16} (depending on wavelength, target material, and focusing parameters)	Monitoring, shielding, restrict personnel access

[a] The irradiance required for LGAC production generally increases with the atomic number (z) of the target material

6.0 Laser System Safety Measures

6.1 Requirements by Laser Class.

Class	Control Measures	Training	LSO	Engineering Controls
1	Not Required	Not Required	Not Required	Not Required
1M	Required	Application Dependent [a]	Application Dependent [a]	Application Dependent [a]
2	Not Required [b]	Not Required [b]	Not Required	Not Required [b]
2M	Required	Application Dependent [a]	Application Dependent [a]	Application Dependent [a]
3R	Not Required [b]	Not Required [b]	Not Required [b]	Not Required [b]
3B	Required	Required	Required	Required
4	Required	Required	Required	Required
NOTE – During maintenance and service, the classification associated with the maximum level of accessible laser radiation shall be used to determine the applicable control measures.				

[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 manufacturers information.

[b] Not required for conditions on intentional intrabeam exposure applications

6.2 Class 1, 2, and 3R Laser Systems.

When used as intended Class 1, 2, and 3R laser systems are generally low hazard devices. The following requirements apply:

6.2.1 Personnel using these classes of lasers, or laser systems, should be trained on proper use of that equipment and understand potential hazards associated with that equipment..

6.2.2 Exposure to laser radiation must be kept below the Maximum Permissible Exposure (MPE) under all conditions of operation or maintenance. The LSO establishes the MPE for each Class 3b and Class 4 laser system and uses the MPE to establish the Nominal Hazard Zone.

6.2.3 Laser systems must have the appropriate warning labels with the laser sunburst logotype symbol and the appropriate cautionary statement.

6.2.4 Removal of protective housing or system modification can increase a laser's classification. See paragraph 11.1.

6.2.5 Use of Class 3R laser with telescopes, microscopes, or alignment devices shall be reviewed by the LSO prior to operation.

6.3 Class 3B Laser Systems

Class 3B lasers or laser systems require a laser hazard analysis, including determination of the MPE and Nominal Hazard Zone (NHZ), by the LSO. The hazard analysis determines the laser control area. Safety measures include:

6.3.1 Only authorized personnel (designated PLUs and Laser Users) may operate Class 3B lasers.

6.3.2 The controlled area must be posted with the appropriate warning signs. Minors (persons under age 18) are not permitted in the controlled area.

6.3.3 At the entryway there must be a visible or audible signal indicating that the laser is energized and operating at Class 3B levels. A lighted laser warning sign or flashing light (visible through protective eyewear) are acceptable entryway warning light alternatives.

6.3.4 All area or entryway safety controls must be designed to allow rapid egress by laser personnel and admittance to the laser controlled area under emergency conditions.

6.3.5 The laser beam path shall be well defined free of obstruction and project into a controlled space.

6.3.6 Windows, doorway, and open portals shall be covered or restricted in such a manner as to reduce the transmitted laser radiation to levels at or below the applicable ocular MPE.

6.3.7 Only diffusely reflecting materials should be in or near the beam path except where optics are used specifically for the purpose of redirecting the laser beam in controlled laboratory settings.

6.3.8 Appropriate protective eyewear shall be readily available and worn.

6.3.9 See paragraph 6.4 for additional requirements and recommendations.

6.4 Class 4 Laser Systems

Must incorporate all of the safety measures for 6.3 Class 3B Laser Systems, in addition to the safety measures listed below:

6.4.1 The control area requires interlocks or alternate controls to preclude the entry of unprotected personnel while laser radiation is present. The interlock system may be designed to preclude entry while the laser is operating or to terminate laser operation when the door is opened without deliberate overriding of the interlock, *or*

6.4.2 A blocking barrier, screen, or curtains must be used to block, screen, or attenuate the laser radiation levels so that MPE is not exceeded at the entry point.

6.5 Engineering Controls for Class 3B and Class 4 Laser Systems.

Some control measures required for Class 3B and 4 lasers are listed in the table below. See Appendix F: Control Measures for the 7 Laser Classes for a summary of additional engineering and administrative controls, PPE, special considerations, and warning signs; for the 7 laser classes. Where specific engineering controls are not feasible they may be replaced with specific administrative and procedural controls and personal protective equipment (PPE) with prior approval of the LSO. Alternative controls and PPE requirements must be documented in a written SOP.

✓ Required ● Recommended	Class 3B	Class 4
Protective Housing – for active laser work with housing off, contact LSO for hazard analysis and appropriate controls	✓	✓
Interlocks on Protective Housing	✓	✓
Service Access Panels Interlocked or tool required and appropriate warning label on the panel	✓	✓
Key Control	●	●
Remote Interlock Connector	●	✓
Beam stop or Attenuator	●	✓
Laser Activation Warning System	✓	✓
Viewing windows, diffuse display screens, or collecting optics (lenses, microscopes, etc.) are controlled with interlocks, filters, or attenuators when necessary to maintain laser radiation at the viewing position at or below the MPE	✓	✓
Enclosed Beam Path	●	●

7.0 Laser System Protection.

7.1 Laser Protective Eyewear.

7.1.1 Eye protection devices that are specifically designed for protection against radiation from Class 3B and Class 4 lasers or laser systems shall be administratively required within the NHZ and their use enforced when engineering or procedural and administrative controls are not practicable. However, if analysis demonstrates that the MPE will not be exceeded due to an extremely short NHZ, then the LSO may not require the administrative use of Laser Eye Protection (LEP). This could occur due to laser beam emission

characteristics (e.g., highly divergent beam), restrictions placed on the use of the laser or laser system (e.g., limited open beam path), or other factors, LEP is not usually required for Class 2 or Class 3R lasers or laser systems except in conditions where intentional long-term (>0.25 s) direct viewing is required.

7.1.2 For all routine laser operations and for most laser alignment procedures, the LEP used shall provide fill protection against a possible direct beam or specular reflection exposure. Use of alignment eyewear shall only be for specific alignment procedures with visible laser beams that have been appropriately evaluated and authorized.

7.1.3 Eyewear must be inspected for scratches, breaks, and cracks before each use, and replaced if necessary, to maintain the eyewear in good condition.

7.1.4 Contact the LSO for assistance in selecting protective eyewear. Factors to consider in selecting appropriate LEP include:

7.1.4.1 Laser power and/or pulse energy.

7.1.4.2 Wavelength(s) of laser output.

7.1.4.3 Potential for multi-wavelength operation.

7.1.4.4 Radiant exposure or irradiance levels for which protection (worst case) is required.

7.1.4.5 Exposure time criteria.

7.1.4.6 Maximum permissible exposure.

7.1.4.7 Optical density requirement of eyewear filters at laser output wavelength.

7.1.4.8 Angular dependence of protection afforded.

7.1.4.9 Visible light transmission requirement and assessment of the effect of the eyewear on the ability to perform tasks while wearing the eyewear.

7.1.4.10 Need for side-shield protection and maximum peripheral vision.

7.1.4.11 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.

7.1.4.12 Need for prescription glasses.

7.1.4.13 Comfort and fit.

7.1.4.14 Degradation of filter media, such as photo bleaching.

7.1.4.15 Strength of materials (resistance to mechanical trauma and shock).

7.1.4.16 Capability of the front surface to produce a hazardous specular reflection.

7.1.4.17 Requirement for anti-fogging design or coatings.

7.1.5 Limitations of Laser Eye Protection

7.1.5.1 Absorptive polycarbonate and glass filters, laminated or dielectric coated (reflective) filters used in the construction of LEP all have physical damage thresholds that may be exceeded under certain conditions.

7.1.5.2 LEP may be inadequate to protect the user from serious ocular exposure from high-power, multi-kilowatt laser beams.

7.1.5.3 Certain dyes used to absorb laser radiation may undergo saturable absorption (a.k.a. induced transmittance or transient photobleaching) where the ability to absorb radiant energy decreases with increasing radiant exposure or peak irradiance. When this occurs, the optical density may decrease providing less protection to the user.

7.1.5.4 Based on the composition of the LEP filter, the angle of exposure can have an effect on the effectiveness of the eyewear filter.

7.2 Skin Protection.

7.2.1 Skin protection can best be achieved through engineering controls. If potential skin damaging exposures exist, skin covers and/or "sun screen" creams are recommended.

7.2.2 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. Consider flame retardant materials for Class 4 lasers.

7.2.3 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.).

7.3 Facility Windows.

Exterior or interior windows that are located within the NHZ of a Class 3B or Class 4 laser must be provided with appropriate absorbing filter, scattering filter, blocking

barrier or screen to reduce any transmitted laser radiation to levels below the applicable MPE level. Important factors for selection include: ability to withstand direct and diffusely scattered beams, flammability and decomposition products of the window material.

7.4 Protective Barriers and Curtains.

A blocking barrier, screen or curtain which can block or filter the laser beam at the entryway should be used inside the controlled area to prevent Class 3B or Class 4 laser light from exiting the area at levels above the applicable MPE level. Important factors for selection include: ability to withstand direct and diffusely scattered beams, flammability and decomposition products of the protective barrier or curtain.

7.5 Laser Generated Air Contaminant Protection.

In general, there are two techniques to protect exposed personnel from LGAC; the use of ventilation and respiratory protection.

7.5.1 Ventilation is the most important protective measure and a primary way to control exposures to LGAC. Ventilation can include protection by general room or local exhaust, or a combination. Local exhaust includes smoke evacuators or wall suction systems. Portable smoke evacuators use various filters and absorbers that require monitoring and replacement on a regular basis. These filters should be considered a possible biohazard and should be disposed of accordingly. To obtain maximum capture, the smoke evacuator nozzle should be placed within two inches of the laser site.

7.5.2 Respiratory protection is a secondary way to control exposures to LGAC if ventilation is not feasible to control exposures. Adequate respiratory protection is generally afforded by a filtering face piece respirator. Use of respirators requires a respirator medical evaluation, fit test, and training by Employee Health and Wellness prior to using the respirator. These requirements apply each year thereafter.

8.0 Laser Warning Signs and Labels.

Laser controlled areas must be posted with the appropriate warning signs at the entryway(s) and if necessary, within the laser controlled area. All signs shall be conspicuously displayed in locations where they best will serve to warn onlookers. All signs in place on or before July 1st, 2016 are considered to fulfill the requirements of this guide. Any new installations, or previous lasers moving locations, shall utilize the current format.

8.1 Warning Signs.

8.1.1 Danger: The signal word “Danger” indicates that death or serious injury will occur if necessary control measures are not implemented to mitigate the hazards

within the laser controlled area. This signal word shall be restricted to those Class 4 lasers with high (e.g., multi-kilowatt) output power or pulse energies with exposed beams..

8.1.2 Warning: The signal word "Warning" shall be used on laser area warning signs associated with lasers or laser systems whose output exceeds the applicable MPE for irradiance, including all Class 3B and most Class 4 lasers and laser systems.

8.1.3 Caution: The single word "Caution" shall be used with all signs and labels associated with Class 2 and Class 2M lasers and laser systems that do not exceed the applicable MPE for irradiance.

NOTE – When a temporary laser controlled area is created, the area outside the temporary area remains Class 1 while the area within is either Class 3B or Class 4. An appropriate warning sign is required within the temporary laser controlled area.

8.2 Laser Equipment Labels.

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 (if separated by more than 2 meters). Lasers or laser systems in most cases are required to be designated for a specific class by the manufacturer in accordance with the FLLPS or IEC 60825-1. These will bear the appropriate laser equipment labels. However, lasers and laser systems classified in accordance with this standard shall have an equipment label that includes the following information:

a) The class of the laser or laser system

b) The emitted wavelength, pulse duration (if appropriate), and maximum output power

c) A precautionary statement for users such as:

1) For Class 2 lasers and laser systems, "Laser Radiation – Do Not Stare into Beam".

2) For Class 2M lasers and laser systems, "Laser Radiation – Do Not Stare into Beam or View Directly with Optical Instruments".

3) For Class 3R and Class 3B lasers or laser systems: "Laser Radiation – Avoid Direct Eye Exposure to Beam".

4) For Class 4 lasers or laser systems, "Laser Radiation – Avoid Eye Exposure to Direct or Scattered Radiation; Avoid Skin Exposure to Direct Radiation".

8.3 Labeling of Protective Equipment.

All laser protective eyewear shall be clearly labeled with the OD and wavelength for which protection is afforded. In addition to the manufacturer's OD and wavelength labeling information, the user may choose to use distinctive identification of LEP in multi-laser environments to aid users in the selection and use of approved eyewear. Although distinctive identification of LEP may be used as a local mechanism to identify eyewear, it does not relieve users from making sure the eyewear is appropriate for their application.

9.0 Training.

9.1 Laser Safety Training.

All faculty, staff, and students who wish to operate Class 3B and Class 4 laser systems at AU shall:

9.1.1 Read this Laser Safety Guide, and

9.1.2 Receive appropriate training from the LSO

9.2 Laser System-Specific Training.

9.2.1 The PLU is responsible for conducting and documenting laboratory-specific safety training for laser users, including a thorough review of the laser equipment, administrative and engineering controls, and alignment and standing operating procedures.

9.2.2 Retraining is required whenever a new laser hazard is introduced into the work area.

10.0 Medical Surveillance.

Baseline laser ophthalmologic exams may be required for Class 3B and Class 4 laser users when designated by the Laser Safety Sub-Committee. Contact Employee Health and Wellness at 706-721-3418 to schedule an appointment.

11.0 Special Considerations.

11.1 Service of Embedded Lasers.

Access to Class 3B or Class 4 lasers or laser systems enclosed within a protective housing or protected area enclosure is limited to properly trained service professionals

and by specific engineering and administrative controls. Contact the LSO for more information.

11.2 Outdoor Controls.

Projection of Class 3R, 3B, or 4 laser beams in the outside environment requires prior review by the LSO and concurrence by the LSS.

11.3 Laser Pointers

Typically Class 2 or Class 3R devices. They are usually hand held and emit a low-divergence visible beam of less than 5 milliwatts. Laser pointers are usually limited to a Class 3R (5 mW) output or less; however, there are more powerful laser pointers available and these devices present a significant potential for an eye injury if viewed directly. Laser pointers are typically used in lecture presentation to identify objects or images. Safety recommendations include:

11.3.1 Never point a laser pointer at anyone, and never look directly into the beam.

11.3.2 Never aim a laser pointer at surfaces that would reflect the light back, such as mirrors or mirrored surfaces.

11.3.3 Purchase only those laser pointer devices with a clear warning on the label about the potential to cause eye damage. Read the instructions carefully, and follow them.

11.3.4 Choose a laser pointer that stays "ON" only when you apply pressure with your fingers. That way you can never leave the beam "ON" by accident.

11.3.5 Choose laser pointers with power that is appropriate to the intended purpose.

12.0 Laser Accidents.

12.1 Immediate response.

For health-threatening injury, including eye or skin injuries, call 1-2911 or proceed directly to a hospital emergency room.

Medical examinations shall be performed as soon as practical (usually within 48 hours) when a suspected injury or adverse effect from a laser exposure occurs.

12.2 Accident Investigation.

12.2.1 The LSO investigates laser accidents and reports findings to the LSS. The investigation includes:

12.2.1.1 Interviews of the injured worker, the PLU, and any witnesses.

12.2.1.2 An examination of the work place to identify contributing factors.

12.2.1.3 A determination of the cause of the accident.

12.2.1.4 Recommendations for corrective actions.

12.2.2 The LSS will review the accident investigation report and determine when and under what conditions laser operations may resume.

12.2.3 The PLU will not resume laser operations until authorized by the LSO.

13.0 Record Keeping.

Environmental Health and Safety shall retain records of Laser Safety Subcommittee meetings, laser system registrations, laser system inventories, laser safety guides, site inspection reports and training records for three years before retiring the records in accordance with AU guidelines.

Appendix A: Acronyms/Abbreviations

AEL – accessible emission limit
ANSI – American National Standards Institute
AU – Augusta University
CDRH – Center for Devices and Radiological Health (USA)
CFR – Code of Federal Regulations
CW – continuous wave
FDA – Food and Drug Administration
FLPPS – Federal Laser Product Performance Standard
Hz - Hertz
IEC – International Electrotechnical Commission
IR – Infrared
J- Joules
Laser – light amplification by stimulated emission of radiation
LCA – laser controlled area
LEP – laser eye protection
LGAC – laser generated air contaminants
LSO – laser safety officer
LSS – laser safety subcommittee
MPE – maximum permissible exposure
PLU – principal laser user
SDS – safety data sheet
NFPA – National Fire Protection Association
NHZ – nominal hazard zone
NOHD – nominal ocular hazard distance
OD – optical density
OSHA – Occupational Safety and Health Administration
PPE – personal protection equipment
SOP – standard operation procedure
UV – ultraviolet

Appendix B: Definitions

Absorption: Transformation of radiant energy to a different form of energy by interaction with matter.

Accessible emission limit (AEL): The maximum accessible emission level permitted within a particular laser hazard class.

Accessible laser radiation: Laser radiation emitted from a laser that is compared with the AEL to determine its hazard class. Includes accessible radiant energy and power.

Administrative control measure: Control measures incorporating administrative means [e.g., training, safety approvals, LSO designation, and standard operating procedures (SOP)] to mitigate the potential hazards associated with laser use.

Alpha max: The angular limit subtense of an extended source beyond which additional subtense does not contribute to the hazard and need not be considered.. *Symbol:* α_{max}.

Alpha min: The angular subtense of a source below which the source can be effectively considered as a point source. The value of alpha min is 1.5 mrad. *Symbol:* α_{min}.

Aperture: An opening, window or lens through which optical radiation can pass.

Apparent visual angle: The angular subtense of the source as calculated from source size and distance from the eye. It is not the beam divergence of the source. *Symbol:* α

Attenuation: The decrease in the radiant flux as it passes through an absorbing or scattering medium.

Authorized personnel: Individuals approved by management to operate, maintain, service, or install laser equipment.

Average power: The total energy in an exposure or emission divided by the duration of exposure or emission. *Symbol:* Φ.

Aversion response: Closure of the eyelid, eye movement, papillary constriction or movement of the head to avoid an exposure to a noxious or bright light stimulant. The aversion response to an exposure from a bright, visible, laser source is assumed to occur within 0.25 seconds, including the blink reflex time.

Beam: A collection of light/photonic rays characterized by direction, diameter (or dimensions) and divergence (or convergence).

Beam diameter: The distance between diametrically opposed points in that cross-section of a beam where the power per unit area is l/e (0.368) times that of the peak power per unit area.

Beam divergence: The increase in the diameter of the laser beam with distance from the beam waist, based on the full angle at the point where the irradiance (or radiant exposure for pulsed lasers) is 1/e times the maximum value.

Carcinogen: An agent potentially capable of causing cancer.

Coherent: A beam of light characterized by a fixed phase relation (spatial coherence) or single wavelength, i.e., monochromatic (temporal coherence).

Collateral radiation: Any electromagnetic radiation, except laser radiation, emitted by a laser system. This does not include laser target interaction (reradiation). Note that reradiation from a target is addressed as a non-beam hazard.

Collecting optics: Lenses or optical instruments having magnification and thereby producing an increase in energy or power density. Such devices may include telescopes, binoculars, microscopes, or loupes

Collimated beam: Effectively, a "parallel" beam of light with very low divergence or convergence.

Conduit: A pipe or hollow cable through which laser energy passes.

Continuous wave (CW): The output of a laser, which is operated in a continuous rather than a pulsed mode. A laser operating with a continuous output for a period > 0.25 sec. is regarded as a CW laser.

Control measure: A means to mitigate potential hazards associated with the use of lasers. Control measures can be divided into three groups: engineering, procedural (administrative), and personal protective equipment.

Controlled area: An area where the occupancy and activity of those within is subject to control and supervision for the purpose of protection from laser radiation hazards.

Cornea: The transparent outer layer of the human eye, which covers the iris and the crystalline lens. The cornea is the main refracting element of the eye.

Diffraction: Deviation of part of a beam, determined by the wave nature of radiation and occurring when the radiation passes the edge of an opaque obstacle. ?

Diffuse reflection: Change of the spatial distribution of a beam of radiation when it is reflected in many directions by a surface or by a medium.

Electromagnetic radiation: The flow of energy consisting of orthogonally vibrating electric and magnetic fields lying transverse to the direction of propagation. Gamma rays, X-ray, ultraviolet, visible, infrared, and radio waves occupy various portions of the electromagnetic spectrum and differ only in frequency, wavelength, or photon energy.

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

Enclosed laser: A laser that is contained within a protective housing of itself or of the laser or laser system in which it is incorporated. Opening or removal of the protective housing provides additional access to laser radiation above the applicable MPE than possible with the protective housing in place. (An embedded laser is an example of one type of enclosed laser.)

Energy: The capacity for doing work. Energy content is commonly used to characterize the output from pulsed lasers, and is generally expressed in joules (J). *Symbol: Q*

Engineering control measure: Control measures designed or incorporated into the laser or laser system (e.g., interlocks, shutters, watch-dog timer) or its application.

Erythema: For the purpose of the ANSI standard, redness of the skin due to exposure from laser radiation.

Eye-safe laser: A Class 1 laser product. Because of the frequent misuse of the term *eye-safe wavelength* to mean *retina-safe,* (e.g., 1500nm to 1800nm) and *eye-safe laser* to refer to a laser emitting at wavelengths outside the retinal-hazard region, the term *eye-safe* can be a misnomer. Hence, the use of term *eye-safe* laser is discouraged.

Fail-safe interlock: An interlock where the failure of a single mechanical or electrical component of the interlock will cause the system to go into, or remain in, a safe mode.

Federal Laser Product Performance Standard (FLPPS): The Center for Devices and Radiological Health (CDRH) is a regulatory bureau within the U.S. Federal Food and Drug Administration (FDA) of the Department of Health and Human Services. CDRH has been chartered by Congress to standardize the performance safety of manufactured laser products. All laser products that have been manufactured and entered into commerce, after August 2, 1976, must comply with these regulations. The regulation is known as the Federal Laser Product Performance Standard (FLPPS), and is identified as 21CFR subchapter parts 1040.10 and 1040.11.

There are three Product Performance Schemes:

1. FLPPS/CDRH 21 CFR 1010 and 1040: For countries that recognize U.S. FLPPS. This should be considered if the laser product is only sold in the U.S.

2. IEC 60825 – 1: For countries that only recognize IEC. For example Europe normally only accepts this format.

3. FLPPS/CDRH + Laser Notice # 50: Recommended scheme for selling to an international market. For example selling both into Europe and the U.S. this option should be used. Laser Notice #50 provides guidance on the conditions under which laser product manufacturers may introduce into United States that comply with the IEC standards 60825-1 and IEC 60601-2-22.

Field of view: The solid angle from which a detector's active area receives radiation.

Focal length: The distance from the secondary nodal point of a lens to the secondary focal point. For a thin lens imaging a distant source, the focal length is the distance between the lens and the focal point.

Focal point: The point toward radiation converges or from which radiation diverges or appears to diverge.

Infrared: For the purposes of the ANSI standard, the region of the electromagnetic spectrum between the long-wavelength extreme of the visible spectrum (700nm) and the shortest microwaves (1000µm)

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

Irradiance: Radiant power incident per unit area upon a surface. Unit: W.cm-2.

Joule (J): A unit of energy. 1 Joule = 1 Watt·second.

Laser: A device that produces radiant energy predominantly by stimulated emission. Laser radiation may be highly coherent temporally, or spatially, or both. LASER is an acronym for **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation.

Laser barrier: A device used to block or attenuate incident direct or diffuse laser radiation. Laser barriers are frequently used during times of service to the laser system when it is desirable to establish a boundary for a controlled laser area.

Laser controlled area (LCA): A laser use area where the occupancy and activity of those within is controlled and supervised. This area may be defined by walls, barriers, or other means. Within this area, potentially hazardous beam exposure is possible.

Laser diode: A laser employing a forward-based semiconductor junction as the active medium.

Laser pointer: A laser product that is usually hand held that emits a low-divergence visible beam and is intended for designating specific objects or images during discussions, lectures or presentations as well as for the aiming of firearms or other visual targeting practice. These products are normally Class 1, Class 2 or Class 3R.

Laser safety officer (LSO): One who has authority and responsibility to monitor and enforce the control of laser hazards and effect the knowledgeable evaluation and control of laser hazards.

Laser system: An assembly of electrical, mechanical, and optical components, which includes a laser.

Lesion: An abnormal change in the structure of an organ or part due to injury or disease.

Limiting aperture: The diameter of a circle over which irradiance or radiant exposure is averaged for purposes of hazard evaluation and classification. Symbol: D_f

Magnified Viewing: Viewing a small object through an optical system that increases the apparent object size. This type of system can make a diverging laser beam more hazardous (e.g., using a magnifying optic to view an optical fiber with a laser beam emitted).

Maintenance: Performance of those adjustments or procedures (specified in the user information provided by the manufacturer, and considered preventative, to maintain optimal performance of the laser system), which are to be carried out by the user to ensure the intended performance of the product. Maintenance does not include *operation* or *service* as defined in this section.

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

Meter: A unit of length in the international system of units; currently defined as the length of a path traversed in vacuum by light during a period of 1/299792458 seconds. Typically, the meter is subdivided into the following units:
Centimeter (cm) = 10^{-2} m
Millimeter (mm) = 10^{-3} m
Micrometer (µm) = 10^{-6} m
Nanometer (nm) = 10^{-9} m

Minimum viewing distance: The minimum distance at which the eye can produce a focused image of a diffuse source, usually assumed to be 10 cm.

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

Nominal ocular hazard distance (NOHD): The distance along the axis of the unobstructed beam from a laser, fiber end, or connector to the human eye beyond which the irradiance or radiant exposure does not exceed the applicable MPE.

Non-beam hazard: All hazards arising from the presence of a laser system, excluding direct human exposure to direct or scattered laser radiation.

Operation: The performance of the laser or laser system over the full range of its intended functions (normal operation). Operation does not include *maintenance* or *service* as defined in this section.

Optically aided viewing: Viewing with a telescopic (binocular) or magnifying optic. Under certain circumstances, viewing with an optical aid can increase the hazard from a laser beam (see telescopic viewing or magnified viewing).

Optical density (OD): The logarithm to the base ten of the reciprocal of the transmittance at a particular wavelength: $D(\lambda) = \log_{10}(1/t\,\lambda)$, where $t\,\lambda$ is transmittance at the wavelength of interest.

Personal protective equipment (PPE): Personal safety protective devices used to mitigate hazards associated with laser use [e.g., laser eye protection (LEP), protective clothing, and gloves].

Photochemical effect: A biological effect produced by a chemical action brought about by the absorption of photons by molecules that alter the molecule.

Plasma radiation: Laser target interaction radiation (LTIR) generated by a plasma.

Power: The rate at which energy is emitted, transferred, or received. Unit: watts (joules per second).

Protective housing: An enclosure that surrounds the laser or laser system that prevents access to laser radiation above the applicable MPE level. The aperture through which the useful beam is emitted is not part of the protective housing. The protective housing may enclose associated optics and a work station and shall limit access to other associated radiant energy emissions and to electrical hazards associated with components and terminals, and may enclose associated optics and a workstation.

Pulse duration: The duration of a laser pulse; usually measured as the time interval between the half-power points on the leading and trailing ends of the pulse. *Symbol: t.* Typical units:
Microsecond (μs) = 10^{-6}s
Nanosecond (ns) = 10^{-9}s
Picosecond (ps) = 10^{-12}s
Femtosecond (μs) = 10^{-15}s

Pulsed laser: A laser, which delivers its energy in the form of a single pulse or a train of pulses. For the purpose of ANSI standard, the duration of a pulse is less than 0.25 sec.

Pupil: The variable aperture in the iris through which light travels to the interior of the eye.

Q-switch: A device for producing very short (»10 – 250 ns), intense laser pulses by enhancing the storage and dumping of electronic energy in and out of the lasing medium, respectively.

Q-switched laser: A laser that emits short (»10 – 250 ns), high-power pulses by means of a Q-switch.

Radian (rad): A unit of angular measure equal to the angle subtended at the center of a circle by an arc whose length is equal to the radius of the circle. 1 radian ≈ 57.3 degrees, 2π radians = 360 degrees.

Radiance: Radiant flux or power output per unit solid angle per unit area. Unit: Watts per centimeter squared per steradian (W. cm-2. sr-1). Symbol: L

Radiant energy: Energy emitted, transferred, or received in the form of radiation. Unit: joule (J).

Radiant exposure: Surface density of the radiant energy received. Unit: joules per centimeter squared (J. cm-2).

Radiant flux (Radiant power): Power emitted, transferred, or received in the form of radiation. Unit: watt (W). Also called radiant power. Symbol: Φ

Reflectance: The ratio of the total reflected radiant power to the total incident power, also called "reflectivity." *Symbol: ρ*

Reflection: Deviation of radiation following incidence on a surface.

Refraction: The bending of a beam of light in transmission through an interface between two dissimilar media or in a medium whose refractive index is a continuous function of position (graded index medium).

Refractive index (of a medium): The ratio of the velocity of light in a vacuum to the velocity of light in the medium. *Symbol: n.*

Repetitive pulsed laser: A laser with multiple pulses of radiant energy occurring in sequence.

Retina: The sensory membrane, which receives the incident image formed by the cornea and lens of the human eye. The retina lines the inside of the eye.

Retina hazard region: Optical radiation with wavelengths between 400nm and 1400nm, where the principal hazard is usually to the retina.

Safety latch: A mechanical device designed to require a conscious decision to override the latch to gain entry to a controlled area.

Saturable absorption: The property of laser eye protection and other optical materials where the absorption of light decreases (OD decreases) with increasing irradiance. This has been shown to occur with certain laser eye protection materials with high-energy nanosecond and shorter duration pulses.

Specular reflection: A mirror-like reflection.

Steradian (sr): The unit of measure for a solid angle. There are 4π steradians about any point is space.

Standard operating procedure (SOP): Formal written description of the safety and administrative procedures to be followed in performing a specific task.

Telescopic viewing: Viewing an object from a long distance with the aid of an optical system that increases the size of the image. The system (e.g., binoculars) generally collects light through larger aperture thus magnifying hazards from large-beam, collimated lasers.

Transmission: Passage of radiation through a medium.

Transmittance: The ratio of transmitted power (energy) to incident power (energy).

Ultraviolet radiation (UV): Electromagnetic radiation with wavelengths between 180nm to 400nm.

Uncontrolled area: An area where the occupancy and activity of those within is not subject to control and supervision for the purpose of protection from radiation hazards.

Viewing window: A visually transparent part of an enclosure that contains a laser process. It may be possible to observe the laser processes through the viewing windows.

Visible luminous (light) transmission: The amount of visible light passing through a filter, weighted for the response of the human eye, express as a percentage.

Visible radiation (light): The term is used to describe electromagnetic radiation that can be detected by the human eye. For purposes of this standard, this term is used to describe wavelengths that lie in the range 400nm to 700nm. Derivative standards may legitimately use 380nm to 780nm for the visible radiation range.

Watt: The unit of power or radiant flux. 1 Watt = 1 Joule-per-second.

Wavelength: The distance in the line of advance of a sinusoidal wave from one point to the next point of corresponding phase (e.g., distance from one peak to the next).

Appendix C: Laser System Registration Form

AUGUSTA UNIVERSITY

Industrial Hygiene and Safety (IHS) Office

Application for Laser Registration

Principal Laser User: _____ Phone #: _____

Department: _____ Location: _____

Type of Laser Use: (Check Each Appropriate Box)

- ☐ Alignment
- ☐ Communication
- ☐ Copying
- ☐ Demonstration
- ☐ Experimentation
- ☐ Instructional
- ☐ Healing Arts
- ☐ Reading
- ☐ Research
- ☐ Other _____

System Information: (Only One Laser per Form)

Manufacturer: _____ Model: _____

Serial Number: _____ Lasing Medium: _____

Wavelength: _____ Maximum Power Output: _____(W or J)

Class: _____

*If Pulsed, complete following questions:

Pulse Duration: _____ (S) Pulse Rep Rate: _____(Hz)

*If Optical Fiber Implemented, complete following questions:

Single or Multi-mode: _____ Numerical Aperture: _____

Brief Description of Use:

_____

_____

Questions or Concerns?

Contact IHS at (706) 721-2663

Signature: _____

Date: _____

Laser Users:

_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

Date:_____

Appendix D: Inspection Checklist

LABORATORY LASER SAFETY INSPECTION CHECKLIST

☐ **Semi-Annual Inspection** ☐ **Follow-up Inspection**

A. Laboratory Specifications:

Department_____Bldg./Room_____
Principal Investigator or Lab Manager:
_____Phone_____
Persons present for inspection _____

B. Equipment and Laser Characteristics:

MEDIUM (Argon, CO2, Nd:YAG, etc.)	CLASS (IIIB or IV)	TYPE (CW or Pulsed)	**WAVE LENGTH(s)** (nm)	**MAX. OUTPUT** (Watts or Joules)	MANUFACTURER	MODEL	**SERIAL NO.**	**PURPOSE OF USE**

C. Laser Posting, Labeling and Security Measures:

	Yes	**No**	**NA**	
1.	☐	☐	☐	Entrance door is labeled with the name and phone numbers of the PI/Lab Manager & Alternate
2.	☐	☐	☐	Entrance door is labeled with Laser Class label
3.	☐	☐	☐	Entrance door is labeled with Laser Hazard label
4.	☐	☐	☐	Entrance door is labeled with Laboratory Hazard Identification Chart
5.	☐	☐	☐	Warning "LASER IN USE" lighted or audible alarm is activated when laser is turned on?
6.	☐	☐	☐	Laboratory security is adequate
7.	☐	☐	☐	Door interlock system is installed and working
8.	☐	☐	☐	Keyed Access to laser lab is only to the authorized personnel

D. Laser Unit Safety Controls:

	Yes	**No**	**NA**	
1.	☐	☐	☐	Protective housing is in place
2.	☐	☐	☐	Fail-safe interlock is installed on removable protective housing
3.	☐	☐	☐	Interlock on housing is functioning
4.	☐	☐	☐	Beam shutter is present
5.	☐	☐	☐	Beam shutter is functioning
6.	☐	☐	☐	Laser activation is indicated on console
7.	☐	☐	☐	Beam power meter is available
8.	☐	☐	☐	Emergency shutoff is available, If yes, where: ☐ near the laser or ☐ at a remote console or ☐ at both places

E. Engineering Safety Controls:

	Yes	No	NA	
1.	☐	☐	☐	Laser is secured to table
2.	☐	☐	☐	Laser optics are secured to prevent stray beams
3.	☐	☐	☐	Optical table is properly grounded
4.	☐	☐	☐	Laser beam is not at eye level in the standing or seated position
5.	☐	☐	☐	Beam is enclosed
6.	☐	☐	☐	Beam barrier(s) is (are) in place
7.	☐	☐	☐	Beam stops are in place
8.	☐	☐	☐	Beam is viewed remotely
9.	☐	☐	☐	Reflective materials are kept out of beam path
10.	☐	☐	☐	Beam alignment procedures are adequate
11.	☐	☐	☐	Stray beams are not seen
12.	☐	☐	☐	Windows in room are covered
13.	☐	☐	☐	There are no Class 4 diffused beams in the operating (occupied) area

F. Administrative Safety Controls:

	Yes	No	NA	
1.	☐	☐	☐	All users have received training within the last 3 years
2.	☐	☐	☐	Training has been documented (certificates available)
3.	☐	☐	☐	Refresher training is attended, within the last 3 years
4.	☐	☐	☐	Authorized users only are working with lasers
5.	☐	☐	☐	Laboratory Standard Operating Procedures (for operation, maintenance and beam alignment) and safety guidelines are developed for use of lasers
6.	☐	☐	☐	Laboratory SOPs have been posted
7.	☐	☐	☐	Laser safety guidelines are posted
8.	☐	☐	☐	Laser safety policy manual is available
9.	☐	☐	☐	Emergency contact list is posted
10.	☐	☐	☐	Baseline eye test has been performed and recorded for all users
11.	☐	☐	☐	Laser is operated under the direct supervision or control of an experienced, trained operator
12.	☐	☐	☐	Protective equipment- eyewear, clothing, barriers, screens, skin protection- are available?
13.	☐	☐	☐	Protective equipment is in good condition
14.	☐	☐	☐	Eyewear is suitable for the wavelength and power/energy of laser

G. Non-Beam Hazards:
If potential for hazards from any of the following exists, describe how these are mitigated (e.g., use of fume hood):

	Yes	No	NA	
1.	☐	☐	☐	Toxic materials
2.	☐	☐	☐	Cryogens
3.	☐	☐	☐	Compressed gases
4.	☐	☐	☐	High voltage power
5.	☐	☐	☐	Collateral radiation
6.	☐	☐	☐	Explosion
7.	☐	☐	☐	Fire
8.	☐	☐	☐	LGAC production
9.	☐	☐	☐	Excessive noise

H. Survey meters:
a) Manufacturer: _____ Model/Serial No.: _____

Suitable for radiant energy/power and wavelength: _____

Calibration performed by: _____Date: _____

b) Manufacturer: _____ Model/Serial No.: _____

Suitable for radiant energy/power and wavelength: _____

Calibration performed by: _____Date: _____

Comments:
_____

_____

_____

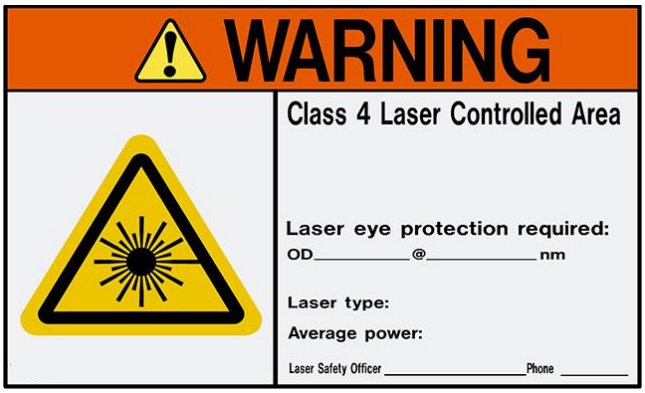
_____

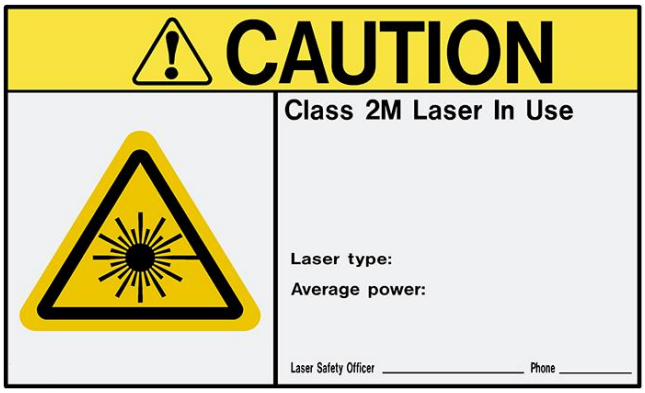
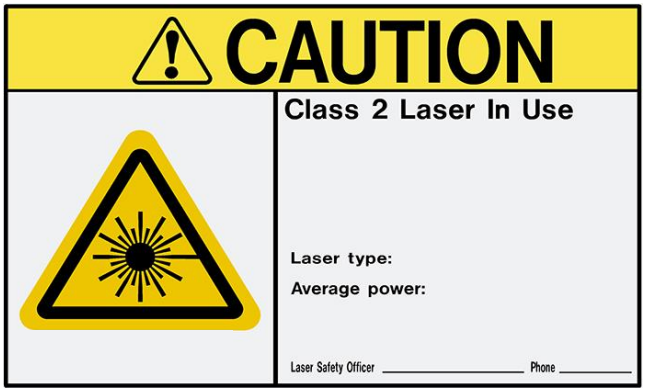
_____

_____

Inspected By: _____ Signature: _____ Date: _____

Appendix E: Warning Signs

Example	Comments
	• Shall be restricted to high (multi-kilowatt) output power or pulse energies with exposed beams. (Class 4) • "**DANGER**" indicates an imminently hazardous situation that, if not avoided, will result in death, or serious injury. This signal word is to be limited to the most extreme conditions.
	• Shall be used on laser area warning signs associated with lasers and laser systems whose output exceeds the applicable MPE for irradiance, including all Class 3B and most Class 4 lasers and laser systems. • "**WARNING**" indicates a hazardous situation that, if not avoided, could result in death or serious injury.
	• Shall be used on laser area warning signs associated with lasers and laser systems whose output exceeds the applicable MPE for irradiance, including all Class 3B and most Class 4 lasers and laser systems. • "**WARNING**" indicates a hazardous situation that, if not avoided, could result in death or serious injury.

Example	Comments
	• Shall be used with all signs and labels associated with Class 2 and Class 2M lasers and laser systems that do not exceed the applicable MPE for irradiance. • "**CAUTION**" indicates a hazardous situation that, if not avoided, could results in minor or moderate injury. It may also be used without the safety alert symbol as an alternative to "NOTICE"
	• Shall be used with all signs and labels associated with Class 2 and Class 2M lasers and laser systems that do not exceed the applicable MPE for irradiance. • "**CAUTION**" indicates a hazardous situation that, if not avoided, could results in minor or moderate injury. It may also be used without the safety alert symbol as an alternative to "NOTICE"
	• "**NOTICE**" is the preferred signal word to address practices not related to personal injury. The safety alert shall not be used with this signal word. As an alternative to "NOTICE," the word "CAUTION" without the safety alert symbol may be used indicate a message not related to personal injury. This signal word shall not be associated directly with a hazard or hazardous situation and shall not be used in place of "DANGER," "WARNING," or "CAUTION."

Appendix F: Control Measures for the 7 Laser Classes

Engineering Control Measures	Classification						
	1	1M	2	2M	3R	3B	4
Protective Housing	X	X	X	X	X	X	X
Without Protective Housing	LSO shall establish Alternative Controls						
Interlocks on Removable Protection Housing	Δ	Δ	Δ	Δ	Δ	X	X
Service Access Panel	Δ	Δ	Δ	Δ	Δ	X	X
Key Control	—	—	—	—	—	●	●
Viewing Windows, Display Screens and Diffuse Display Screens	Ensure viewing limited < MPE						
Collecting Optics	X	X	X	X	X	X	X
Fully Open Beam Path	—	—	—	—	—	X NHZ	X NHZ
Limited Open Beam Path	—	—	—	—	—	X NHZ	X NHZ
Enclosed Beam Path	None, if required controls for Protective Housing and Interlocks on Removable Protective Housings are fulfilled						
Area Warning Device	—	—	—	—	—	●	X
Laser Radiation Emission Warning	—	—	—	—	—	●	X
Class 4 Laser Controlled Area	—	—	—	—	—	—	X
Entryway Controls	—	—	—	—	—	—	X
Protective Barriers and Curtains	—	—	—	—	—	●	●

"X" – Shall
"●" – Should
"—" – No Requirement
"Δ" – Shall if enclosed Class 3B or Class 4
"NHZ" – Nominal Hazard Zone analysis required

Administrative (and Procedural) Control Measures	Classification						
	1	1M	2	2M	3R	3B	4
Standard Operating Procedures	—	—	—	—	—	●	X
Output Emission Limitations	—	—	—	—	LSO Determination		
Education and Training	—	●	●	●	●	X	X
Authorized Personnel	—	—	—	—	—	X	X
Indoor Laser Controlled Area	—	○	—	○	—	X NHZ	X NHZ
Class 4 Laser Controlled Area	—	—	—	—	—	—	X
Temporary Laser Controlled Area	Δ MPE	Δ MPE	Δ MPE	Δ MPE	Δ MPE	—	—
Controlled Operation	—	—	—	—	—	—	●
Outdoor Control Measures	X	○ MHZ	X NHZ	○ MHZ	X NHZ	X NHZ	X NHZ
Laser in Navigable Airspace	●	●	●	●	●	●	●
Alignment Procedures	Δ	X	X	X	X	X	X
Spectators	—	○	—	○	—	●	X
Service Personnel							

"X" – Shall
"●" – Should
"—" – No Requirement
"Δ" – 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

Personal Protective Equipment (PPE)	Classification						
	1	1M	2	2M	3R	3B	4
Laser Eye Protection	—	—	—	—	—	X	X
Skin Protection	—	—	—	—	—	●	●
Protective Clothing	—	—	—	—	—	●	●

"X" – Shall
"●" – Should
"—" – No Requirement

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

"X" – Shall
"—" – No Requirements
"MPE" – Shall if MPE is exceeded
"NHZ" – Nominal Hazard Zone analysis required

Appendix G: Standard Operating Procedure Template

Dept.:	Date: MM/DD/YY
Procedure:	Revision #:
Principal Authorize Laser User:	

- **This procedure shall be read and signed <u>annually</u> by all persons who use lasers listed in this SOP.**
- **This procedure shall be reviewed <u>every two years</u> by the PLU to ensure it reflects the most current conditions.**

1. LASER SAFETY CONTACTS

Laser Safety Officer (LSO): (706) 721- 2583

Medical Emergencies

1. **Call (706) 721-2911**
2. Notify the Laser Safety Officer of all laser-related injuries and near-misses ASAP

2. LASER DESCRIPTION

Attach latest Laser Inventory. Register each laser in accordance with the AU Laser Safety Guide. Update as required.

3. LASER SAFETY PROGRAM

Refer to the Laser Safety Guide: http://www.augusta.edu/services/ehs/lasersafetyoff/

- Responsibilities of the laser operator, and Laser Safety Officer
- Laser Registration Requirements
- Training Requirements
- Disposal Procedures
- Sign and Labeling requirements
- Eyewear requirements, including eyewear inspections every six months

4. HAZARDS & CONTROLS

HAZARDS AND CONTROLS		
Check if applicable	**Hazard**	**Control(s)**
☐	High Voltage	
☐	Capacitors	
☐	Unenclosed Beam/Access to Beam	
☐	Fumes/Vapors	
☐	UV Radiation or Blue Light	
☐	Compressed Gases	
☐	Hazardous Chemicals/Waste	
☐	Housekeeping	
☐	Reflective Material in Beam Path	
☐	Fire	
☐	Laser at eye level of person sitting or standing	
☐	Entryway (door) Interlocks or controls	
☐	Laser Enclosure Interlocks	
☐	Laser Housing interlocks	
☐	Panic button/Emergency stop	
☐	Beam Stops	
☐	Master Switch (operated by key or computer code)	
☐	Laser secured to base	
☐		
☐		

5. PERSONAL PROTECTIVE EQUIPMENT

A. Eyewear

LASER EYEWEAR					
For this laser…			…Wear this eyewear		
Entry Number	Type	Wavelength (nm)	Wavelength attenuated (nm)	Optical Density (OD)	Remarks
1					
2					
3					
4					
5					
6					
7					
8					

B. Other protective equipment required in this area includes:

What (item):	And is available from (where):	Which must be worn (when):
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

6. OPERATING PROCEDURES

A. Initial preparation of lab environment for normal operation (key position, warning lights on, interlock activated, identification of personnel, other)

B. Target area preparation

C. Operation procedures are as follows:

D. Shutdown procedures for this laser are as follows:

E. Special procedures (alignment, safety tests, interlock bypass, emergency, etc.)

7. LASER USER REVIEW

I have read this procedure and understand its contents.

Name (print)	Signature	Date: MM/DD/YY

Appendix H: Laser Accident Response Plan Template

LASER ACCIDENT EMERGENCY PROCEDURE

Laser Description: _____ Class: _____

Location: _____

Principal Laser User: _____

Implement the following procedures in the event that someone suffers a laser eye injury or skin injury:

1. Immediately turn off the laser, unplug it if possible, and quickly post a prominent notice stating "Do not use – laser accident" or an equivalent cautionary statement to ensure it is not used again until approval is obtained from the Laser Safety Subcommittee. To turn off this laser complete the following actions:
   _____
   _____
   _____
2. Keep the injured person calm. If a retinal injury is suspected and there is bleeding inside of the eye, keep the injured person in an upright, seated position.

3. Arrange for transportation of the injured person for medical evaluation and treatment. Avoid having the injured worker self-transport as he/she might be in shock or have impaired vision. If necessary call Public Safety for assistance at (706) 721-2911.

4. Notify the Principal Laser Users (PLU). The PLU for this laser can be reached at _____ during normal work hours and _____ after normal work hours.

5. Contact the Laser Safety Officer (LSO). The Laser Safety Officer can be reached at (706) 721-2583 during normal work hours and (706) 721-2911 after normal work hours by requesting EHS On-Call Assistance.

_____ Date: _____

Principal Laser User