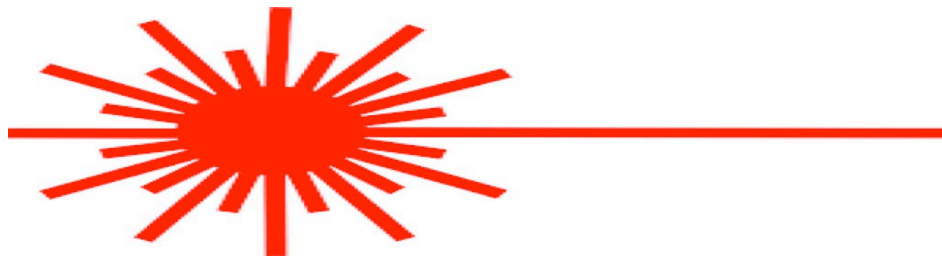


The George Washington University Laser Safety Manual



Office of Research Safety
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1. Introduction

Laser is an acronym for Light Amplification by Stimulated Emission of Radiation. A laser is electromagnetic radiation that is usually monochromatic, spatially coherent, and has a narrow divergence. These beams can have energy in the ultraviolet, visible, and infrared spectrums. The hazards associated with lasers are primarily associated with the eye and skin. These hazards are what this manual aims to mitigate or eliminate.

The George Washington University has a multitude of lasers on campus that vary with power output and wavelength of the photons. Each poses differing hazards and classification of these hazards can be complex. After understanding the material in this manual, however, an operator will have the knowledge necessary to work safely with lasers.

2. Scope and Responsibilities

The Office of Research Safety (ORS) is responsible for the Laser Safety Program at GWU. The Radiation Safety Officer or designee serves as Laser Safety Officer (LSO) for the University, including the Mount Vernon and Virginia campuses. The LSO is responsible for the implementation and compliance of laboratories with the Laser Safety Program. Any registration or notification to local, state, and federal agencies as required is the responsibility of the LSO.

Additionally, the each department that operates lasers must designate a Deputy Laser Safety Officer (DLSO) to aid in compliance with applicable requirements and regulations. Usually, the DLSO is a researcher and operator of the specific laser(s) they are responsible for. This person is responsible to help oversee routine use of the laser to ensure that all operators are using the equipment properly. The DLSO is the primary contact between ORS and their respective department or laboratory. Any change in the DLSO must be reported to ORS within 24 hours.

The guidelines for laser safety that are outlined in the manual are from the *American National Standard for Safe Use of Lasers* (ANSI Z136.1 – 2007), published by the American National Standards Institute and the Laser Institute of America. A copy of this standard is with ORS in Ross B05 for review. Unfortunately, this copy must stay in the office and is not available as a loaner.

A laser operator has primary responsibility to ensure that the laser is operated safely and to minimize hazards. This is accomplished through understanding training, standard operating procedures, the device manual, and how the various protective elements (personal protective equipment (PPE), engineering controls, administrative controls, etc.) mitigate risks. The principal investigator (PI) is responsible for maintaining a safe environment for laser use, training of operators

on individual laser systems, providing adequate PPE, labeling all equipment and rooms, and notifying ORS of any incident, accident, or change to existing laser systems.

3. Acquisition Procedures

All operable lasers used in research and laboratories must have documentation on file with ORS. This written notice shall include the party responsible for the laser, as well as the specifications and location of the laser. Please refer to the Laser Inventory Form. Once the laser or laser system has been installed, ORS will perform a hazard evaluation to assure appropriate safeguards and protocols are in place.

If a laser system that has been inoperable is brought back into research, please make sure to fill out an inventory form as if it was brand new. Additionally, if a laser has been significantly modified through optics or safeguards an inventory form for the new system needs to be on file. Significantly modified can be when a laser's class has been changed due to optically concentrating the beam or interlocking the device down to a lower class.

4. Work Practices

Prior to operation of a laser, the DLSO shall ensure that a written Standard Operating Procedure (SOP) plan is developed. The plan will describe the intended use of the laser device, its associated safety features, and the process to assure the safety to all persons in the vicinity of the laser system. The SOP should discuss all of the major hazards associated with the system. The LSO is responsible for determining that the SOP is specific to each laser device.

The LSO and DLSO shall ensure that all users understand the SOP, basic laser fundamentals and safety principles, as well as PPE requirements before users work with the system. All appropriate signs and labels must be in place prior to the operation of a laser.

When a laser is activated it must not be left unattended without appropriate safeguards enabled. These safeguards must identify the hazard of an activated laser or prevent access to the laser beam. When a class 3B or 4 laser system is not in use it should be disabled by means of a key to prevent an accidental discharge by untrained operators.

Classification of lasers is performed by laser manufacturers as regulated by the FDA. Lasers, however, must be classified according to how they are used. Therefore, if attenuators or optics are used to diffuse or concentrate the accessible beam, the laser classification may change accordingly. If you have altered the beam in anyway contact ORS to perform a calculation to determine if

your laser class has changed. This may require a new inventory form to be filled out according to [section 3](#).

The LSO is responsible for an annual audit on all research and laboratory laser systems. These audits will ensure that the safeguards associated with each laser are being properly implemented. The audit provides a time to determine that all systems comply with this laser safety program, as well as a time for operators to resolve any discrepancies they may find between their use of lasers and this program, regulations, or national standards.

5. Training

The LSO is responsible for developing a laser safety training program for all research and laboratory laser operators. Records for training must be maintained for a period of 5 years beyond the date of termination or end of enrollment as an operator. Please see Appendix E for a more detailed explanation.

Training for Class 3B and 4 lasers will be provided by ORS. This is mandatory for all operators of Class 3B and 4 lasers to ensure awareness of hazards and the details of GWU's laser safety program.

Training for all other classes of lasers requires operators to read through and understand the laser safety training located on the ORS website. Documentation for this training must be submitted to ORS by the DLSO prior to operation of the laser. The acknowledgment of training form is on the website.

Training for the DLSO may involve a more detailed analysis of the regulations and requirements of the laser safety program than that for operators. A DLSO should have working knowledge of all laser devices for which they are responsible. Examples of required SOPs and training guidelines can be provided by ORS.

Training on the specific laser SOP is the responsibility of the PI and DLSO. Each laser system should be discussed with an operator to identify the various hazards associated with each. This training should be documented and kept accessible by each laboratory to provide in case of an accident or near-miss scenario.

6. Emergency Procedures and Accident Reporting

In the event of a laser incident that involves non-routine operating events, such as injury or damage to property, immediately shut the laser off and remove the interlock key (if applicable). If the incident involves a major event such as fire or debilitating injury, immediately contact 911, and take the necessary steps to avoid further injury (e.g. egress in the event of fire or stabilization in the case of

injury). If the incidents results in a minor injury direct the operator to fill out a incident report form.

The DLSO is responsible for notifying ORS within 24 hours of any accident or near-miss scenario involving a laser device. Lasers involved in an accident shall be taken out of service immediately. The LSO shall be responsible, with the assistance of the DLSO and/or PI, for evaluating the accident and safety of the laser device.

Appendices

Appendix A: Laser Light Physics

Laser light is created through the introduction of energy into a lasing medium, causing an excitation of electrons, which release this energy as photons in a monochromatic (single wavelength), coherent (consistent), and directional (does not scatter) beam. The lasing medium can be solid state, gas, organic dye, or a semiconductor, however, each produces laser through the excitation of electrons. Laser light from a device is either a continuous wave or of a pulsed duration. Pulsed lasers are able to have a much higher energy but usually are of short duration.

Laser light will be classified depending on if it is in the ultraviolet, visible, or infrared band of the electromagnetic spectrum. Ultraviolet light has the shortest wavelengths and highest energy with infrared having longer wavelengths and less energetic photons. Ultraviolet light ranges from 200-400 nm. Visible light is in the 400-760 nm range. Infrared light has wavelengths from 760-10000 nm.

Laser light can also pose a hazard due to reflection from surfaces. Only high powered lasers pose a reflection hazard. Some surfaces that appear dull can be specular reflectors of infrared light, while some surfaces that appear shiny may be diffuse reflectors of ultraviolet light. Therefore, always take special precaution that your laser stop is not a reflector.

Appendix B: Biological Hazards

Lasers pose risks to both the eyes and the skin. Most skin hazards are primarily in the ultraviolet range, however high powered visible and infrared lasers can cause skin burns and set clothing on fire. These biological hazards to the skin include pigmentation changes and potential skin cancer in the ultraviolet range.

Eye hazards are much more complex as various wavelengths affect differing parts of the eye. Due to the complex nature of the eye various wavelengths affect different parts of the eye. The following chart is a breakdown of the location and effect of laser light on the eye.

Wavelength (nm)	Area of Damage	Pathological Effect
180-315 UV-B, UV-C	Cornea; accumulating damage during day	Photokeratitis: Inflammation of the cornea, similar to sunburn
315-400 UV-A	Cornea and Lens	Photochemical cataract: Clouding of the lens
400-760 Visible	Retina; where visible light is focused	Photochemical damage to retina
760-1400 Near Infrared	Retina	Thermal damage to retina
1400-3000 Mid Infrared	Cornea and Lens	Aqueous flare: protein in front of eye burns
3000-10000 Far Infrared	Cornea	Corneal burn

Damage to the cornea will typically heal between 48 hours and week after injury, if it's a surface injury. Deeper damage can be permanent. Damage to the lens of the eye usually results in a decrease in clear vision through hardening or cataracts. The retina is where the photoreceptor nerve cells are located. These cells transmit the information of light (presence/intensity) to the brain for sight. Retina is easily damaged and laser strikes can result in blind spots, with repeated burns that may ultimately result in blindness. The macula and fovea are the most important part of the retina for detailed and acute vision. Damage to these areas is more likely to result in permanent vision problems.

Appendix C: Laser Classification

Lasers are classified based on their capacity to produce biological injury to the eye or skin. This is outlined in the ANSI standard and all lasers must have the updated classification numbers. Lasers are classified as follows:

Class 1 – Laser systems that can never emit laser radiation levels in excess of the maximum permissible exposure (MPE) and therefore are considered incapable of causing eye damage.

Class 2 – Laser systems that emit visible laser light that are incapable of produce eye damage as protection is normally afforded by the aversion response

Class 1M/2M – Laser systems that fall under class 1 or 2 systems, however, can produce hazardous situations if viewed with optical instruments.

Class 3R – Laser systems that may be hazardous under direct and specularly reflected beam situations, but are normally not hazardous if viewed only for momentary periods with an unprotected eye. Includes visible and invisible laser radiation.

Class 3B – Laser systems that are hazardous under direct and specularly reflected beam situations. Diffusely reflective surfaces usually provide little risk. The eye's aversion provides no protection from the beam.

Class 4 – Laser systems of a high power that are hazardous to both the eye and skin. Any form of reflection can pose a hazard. Depending on wavelength class 4 lasers may be a fire hazard.

Appendix D: Non-Beam Hazards

In addition to the beam hazards, operators must be aware of non-beam hazards associated with laser systems. The following is an example of some of the more prevalent of these hazards:

Electrical Hazard – Many class 3B and 4 lasers have large power sources that have enough voltage to injure or kill.

Fire Hazard – Class 4 lasers can ignite flammable material, including paper, therefore a fire extinguisher must be on hand during operation.

Laser Generated Air Contaminants (LGAC) – Certain laser systems may create air contaminants due to interaction of the laser beam with the target material. Adequate ventilation or filtration must be used if these contaminants pose a significant hazard.

Chemical Hazard – Many laser systems contain hazardous chemicals that may be toxic or carcinogenic. Be sure to check the MSDS that comes with the laser system to determine if there is any additional precautions that need to be taken.

Compressed Gases – Compressed gases are often used in association with laser systems. Be sure that the gases and tanks are in compliance with the GWU compressed gas requirements.

Collateral & Plasma Radiation – Additional radiation hazards to the laser itself can come from high voltage supplies, plasma tubes, discharge lamps, etc. This radiation can come in a variety of forms along the EM spectrum including x-rays.

Noise – Laser systems, especially pulsed lasers, may produce noise that is in excess of 90 dB. These systems will also require noise protection.

Appendix E: Laser Trainings Offered

The Laser Safety Officer (LSO) shall ensure that all laser operators are qualified and trained. The training program should be designed according to the class of laser used. The LSO shall maintain documentation of training including the names of personnel trained and the dates of when training was conducted. Upon completion of the training, documentation must be provided to the Office of Research Safety.

A. CLASS 1 TRAINING:

Class 1 training can be limited, in general, to information contained in the operation/maintenance manuals of the laser manufacturer. No additional operator training is necessary provided the Class 1 status is maintained.

B. CLASS 1M, CLASS 2, CLASS 2M AND CLASS 3R TRAINING:

Class 1M, Class 2, Class 2M, and Class 3R training should include information contained in the operation/maintenance manuals of the laser manufacturer and, where appropriate, additional basic laser safety guidelines. Additionally, laser operators must have documented that they have read through the GWU Laser Safety presentation.

C. CLASS 3B AND CLASS 4 TRAINING:

Personnel working with these lasers must take the online laser safety training provided by the ORS and the Principal Investigator is responsible for providing instruction in the safe and appropriate use of the laser related to the specific research project. Register for the online training by emailing ORS at labsafety@gwu.edu. The training consists of the revision of the GW Laser Safety Presentation (PDF) and quiz.

D. DEPUTY LASER SAFETY OFFICER TRAINING:

The DSLO should take the ORS training and make an in-depth review of the appropriate standards, OSHA requirements, and needs for state and local compliance. Our office has a copy of the American National Standard for Safe Use of Lasers (ANZI Z136) for you to view if needed.

E. TAILORED TRAINING SESSIONS:

There often will be a need to tailor the laser safety training session for each of the different groups that use lasers in the facility. Often the type of laser(s) and locations will impact the content of the training program. For example, the hazards and controls recommended for the far-infrared CO(2) lasers are usually different than those for a near-infrared Nd:YAG laser or a visible Argon Ion laser. If a laboratory would like a more detailed training on its laser system please contact ORS.