LASER SAFETY MANUAL

Scope

In order to protect the University of Georgia's faculty, staff, researchers, students, and visitors, from potentially hazardous levels of radiation associated with laser use, a laser safety program must be implemented. This laser safety manual applies to all students, researchers, faculty, staff, and visitors using lasers or laser systems at the University of Georgia. Class 3b and 4 lasers are of primary concern. However, when modifying or servicing Class 1 or 2 laser systems with embedded Class 3b or 4 lasers, appropriate precautions must be taken for the embedded laser when the potential for exposure exists.

Objectives

The objectives of the laser safety program are as follows:

- to encourage responsible behaviors that will promote safe laser use at UGA campus and off-campus facilities
- to follow the American National Standards Institute's Safe Use of Lasers (ANSI 136.1-2000) as a guideline for safe laser use and injury prevention
- to comply with the state of Georgia Department of Human Resources rules and regulations of Laser Radiation (Chapter 290-5-27)
- to ensure timely registration and reporting of major modification of laser systems that may introduce new safety issues
- to ensure reporting of any exposure or injury due to laser radiation
- to assure that basic laser safety training is accessible and that all personnel operating Class 3b and 4 laser systems are adequately trained for the appropriate laser system
- to provide objective and reliable laser safety information to University employees
- to encourage cooperation and networking among faculty, staff, researchers, and laser safety professionals

Safety and Responsibility

DEPARTMENTAL SAFETY OFFICER (DSO)

Each department using lasers should designate a safety officer to serve as an advisor to and oversee the registered users. This person should be responsible for ensuring that registered users have all lasers registered and operate their lasers and/or laser systems in a safe manner that follows guidelines outlined in this manual.

REGISTERED USER

The registered user is the faculty member, staff member, or director of a contract/private lab in control of the laser or laser system. This person must have all lasers and laser systems registered with the State of Georgia Department of Human Resources and Public Health. They will also be responsible for the safe operation of the laser system and for the safety of those using their laser system. These tasks include, but are not limited to:

- assuring lab personnel and authorized users within the laser control area receive adequate laser safety training, and access to laser safety manuals, SOP, MSDS, and any other information pertinent to laser safety before operation of laser equipment
- implementing appropriate control measures to reduce exposure to harmful levels of laser radiation, and assuring all feasible safety precautions are taken ensure safe use of laser equipment
- providing lab personnel and authorized users with personal protective equipment in good condition that is appropriate for the laser being used
- posting of signs and labels according to ANSI Z136.1 standards
- writing and updating standard operating procedures for laser equipment
- documenting of laser safety training for lab students and laser personnel
- reporting of accidents and possible exposures to the DSO and ESD

AUTHORIZED USERS

Authorized users include those working with or around lasers (i.e. operators, technicians, maintenance, and service personnel). Laser safety training should be provided to those routinely working in laser environments. Only qualified personnel should carry out servicing and maintenance of class 3b and 4 lasers (with the exception of the vendor's qualified service personnel). Authorized users should not energize or work with or near a laser unless authorized by the registered user.

LAB STUDENTS

Students working under a registered user may use lasers in the lab after completing laser safety training and training in operation of the particular laser or laser system. Their responsibilities are:

- familiarity with operating procedures
- awareness of visitors/spectators in the area
- compliance with the safety rules and regulations
- termination of laser system operation if hazards exist
- immediate reporting of any laser accident to the registered user, DSO, or ESD

VISITORS AND SPECTATORS

Visitors and spectators are not allowed in a laser area without approval of the registered user. The registered user or authorized user must supervise visitors and spectators approved by the registered user during laser system operation.

State and Federal Standards

There are several regulations and standards that apply to lasers and their use. Priority should be given to state and federal regulations such as the Georgia Rules and Regulations, and those of the Occupational Safety and Health Administration (OSHA) as they apply to use at the University of Georgia. The American National Standards Institute (ANSI Z136.1, Z136.2, Z136.3) publishes recommendations regarding laser safety, and should be used as a guideline. The Joint Commission of Accreditation of Healthcare Organizations (JCAHO) follows ANSI standards for medical use of lasers. The International Electrotechnical Commission (IEC) and the Federal Laser Products and Performance

Standards (FLPPS) have standards that apply to those assembling and manufacturing lasers and laser systems.

STATE OF GEORGIA RULES AND REGULATIONS (CHAPTER 290-5-27)

The State of Georgia Department of Human Resources and Public Health has rules and regulations regarding registration, injury reporting, and report of discontinuance of lasers and laser systems used.

1. Registration
   No person may possess or operate a laser system without first registering in writing. Any person acquiring a laser system after the effective date of these rules shall register within 30 days after the date of acquisition. The Department of Human Resources and Public Health, at intervals considered necessary to maintain a current inventory, may require re-registration of laser systems. Any person possessing or operating a laser system may apply in writing for blanket registration of the laser system if registration of each source of laser radiation by type or strength is considered impractical. All applications for registration shall be in writing, on forms provided by the department, to include the following:
   a. name and address of person possessing or operating the laser system
   b. identification and type of the laser system
   c. location of the laser system
   d. for continuous-wave lasers, the maximum power level at which the laser can be operated
   e. for pulse lasers, the maximum energy per pulse, pulse duration, and the maximum pulse repetition rate at which the laser can be operated
   f. the wavelength at which the laser can be operated
   g. other pertinent information that may be required by the department to ascertain the identification, type, location, and operational characteristics of the laser system.
2. Injury Reporting
   a. Any person possessing or operating a laser system shall report, in writing, to the department within fifteen days of detection of any injury to an individual, regardless of severity or extent, in the course of operating, handling, servicing, or manufacturing a laser system.
3. Report of Discontinuance
   b. Every person who has registered a laser system and who permanently discontinues the operation of, or permanently disposes of, his laser system shall notify the department, in writing, within thirty days of such action.

OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION (29 CFR 1926)

The Occupational Safety and Health Administration, Department of Labor has broad coverage concerning personal protective equipment, maintenance, electrical safety, training, airborne contaminants, ventilation, medical services, first aid, emergency action plans, and general safety and health that apply to safety in a laser environment. As a minimum standard of care, the laser safety program will adopt the following guidelines taken from 29 CFR 1926.54 Subpart D (Occupational Health and Environmental Controls) on nonionizing radiation:

1. Only qualified and trained employees shall install, adjust, and operate laser equipment.

2. The operator must have proof of qualification of the laser equipment present.
3. Employees shall be provided eye protection when an exposure greater than 5 mW exists.
4. Standard laser warning placards shall be posted in all areas where lasers are used.
5. Beam shutters or caps shall be utilized, or laser turned off when laser transmission is not actually required. Laser must be shut off when left unattended for a substantial period of time.
6. Only mechanical or electronic means shall be used for internal alignment procedures (viewing scopes, cards, ect.)
7. Laser beams shall not be directed at employees.
8. Operation of laser systems is prohibited when rain, snow, fog, or dust (in large quantities) is present in the air. Employees should be kept out of range of the area of source and target during such weather conditions.
9. Laser equipment shall bear a label indicating maximum output.
10. Employees shall not be exposed to light intensities above:
    a. 1 $\mu W/cm^2$ - direct staring
    b. 1 mW/cm^2 - incidental observing
    c. 2½ W/cm^2 - diffused reflected light
11. When possible, laser unit should be set at a level that will avoid direct eye exposures to those seated or standing in the vicinity of the laser during operation.

AMERICAN NATIONAL STANDARD FOR SAFE USE OF LASERS (ANSI Z136.1 - 2000)

The American National Standard Institute, Inc. published the laser standards to be used as a guideline for the safe use of lasers and laser systems. There are standards that specifically pertain to lasers used in medical applications (ANSI Z136.3) and fiber optics (ANSI Z136.2) however; this manual will make reference only to ANSI Z136.1. Entities using lasers for fiber optics and medical applications should confer with those manuals.

The ANSI laser standards are intended to make recommendations for those using lasers and laser systems that operate at wavelengths between 180 nm and 1 mm. Lasers and laser systems are classified according to potential hazards and are assigned appropriate controls. There should be no need for calculations to meet the standard unless a change is made to the laser or laser system, which may require reclassification (i.e., system alterations). Environmental and personal factors, such as training and conditions under which the laser is used, should also be considered when determining these controls. If engineering controls suggested by the standard are impractical, administrative and procedural controls and personal protective equipment shall be used.

FDA FEDERAL LASER PRODUCTS AND PERFORMANCE STANDARDS (21 CFR 1040)

Performance standards for light-emitting products apply to those manufacturing or assembling lasers and those lasers manufactured or assembled after August 1, 1976. The standards include classification, records, reports, and informational, performance, and labeling requirements that should be followed by laser users. Laser products are not considered “manufactured” provided they are:

1. not shipped in interstate commerce

2. used solely at the place where constructed
3. used by the same employees who constructed them
4. not made on a recurring basis
5. constructed on a one-time basis by a particular entity, and made for use in that entity's manufacturing process in the place where constructed

INTERNATIONAL ELECTROTECHNICAL COMMISSION (IEC)

The IEC is a global organization that prepares and publishes international standards for all electronic and related technologies. These standards also apply to those manufacturing or assembling lasers.

JOINT COMMISSION OF ACCREDITATION OF HEALTHCARE ORGANIZATIONS (JCAHO)

JCAHO is a credentialing organization. Regarding laser safety, they follow standards of care as outlined in ANSI Z136.3. JCAHO applies to all outpatient surgery facilities including hospital-based facilities, freestanding centers, and office based surgical suites. Any lasers used for medical reasons on campus should be in compliance with these standards.

Classification of Lasers and Laser Systems

The purpose of the laser classification system is to assign lasers to specific hazard categories based on maximum output available for intended use, which in turn reflects their ability to cause injury. This will aid in hazard evaluation and assist in applying appropriate control measures. The Federal Laser Product classification scheme is as follows:

Class	Allowable Power (watts)	Emission Duration (sec)	Relative Output Power	Relative Hazard
1	0.39×10^{-6}	>10,000	Extremely low	None known
2a	0.39×10^{-6}	>1,000	Very, very low	Very low
2	0.001	>0.25	Very low	Low
3a	0.005	>0.00038	Low	Low to moderate
3b	0.05	>0.25	Moderate	Moderate to high
4	>0.5	----	High	High

*Keep in mind that the environment in which the laser is used and the personnel using or exposed to laser radiation also influence hazard classification and controls to be used.

Laser Hazards

Lasers can pose health risks if used incorrectly or in a careless manner. Laser hazards can be a result of direct or reflected beam exposure or from ancillary sources. All precautions must be taken to prevent potentially dangerous exposures.

BEAM HAZARDS

Beam hazards are those from direct and indirect beam exposures which can result in damage to the eyes and skin. Although the skin is more susceptible to exposure due to a larger surface area, the eyes are more vulnerable to laser radiation. Biological effects due to laser radiation differ according to the exposure duration, irradiance, and wavelength. Penetration is wavelength dependent with photochemical, photomechanical, or thermal damage mechanisms. There are several means to prevent exposure to laser radiation including PPE, engineering, and administrative controls.

Eyes

The greatest hazard from laser radiation is damage to the eyes from intra-beam viewing, specular, or diffuse reflections. Structures susceptible to injury are the iris, cornea, lens, retina, and optic nerve. Eye exposure can result in temporary impairment, hemorrhaging, scarring, erythema, photo-keratitis, retinal images and burns, cataracts, and corneal burns.

Skin

Laser radiation can induce multiple reflections in addition to being absorbed and transmitted into the skin due to the diverse composition of the skin structures. The extent of absorption is related to the wavelength, exposure duration, and location (to some extent). IR wavelengths deeply penetrate the skin and cause thermal effects such as warmth, pain, swelling, whitening of the skin, or burns. UV laser radiation causes photochemical effects such as dimerization and photosensitization.

ANCILLARY HAZARDS

Ancillary hazards are those hazards not associated with direct human exposure to the laser beam. These hazards can be a result of: exposure of a material to a laser beam, components of the laser system, materials used to generate the laser beam, or where and how the laser system was used. Non-beam hazards can be life threatening in some cases, so control measures should be carried out and taken seriously. When management of ancillary hazards extends beyond the expertise of the registered user or DSO, he/she may employ qualified personnel to assist in the evaluation and control of the hazard.

Electrical Hazards

Shock and electrocution are the primary hazards associated with lasers and laser systems, especially those associated with high voltage power supplies. In order to avoid electrical hazards, care should be taken during servicing, testing, modification, maintenance, or any other activity that requires contact with energized components of the laser system. Electrical protection parameters, connection to the utilization system, and safety training should comply with OSHA, the National Electric Code (NEC), National Fire Protection Association (NFPA), and any other applicable state and local laws and regulations.

Fire/Explosion Hazards

Fires can result due to contact of a laser beam with lasing material, gases, materials used in generation of the laser beam, laser curtains, unprotected wire insulation, and plastic tubing. While class 4 laser beams present the highest hazard potential for fire (irradiance exceeding 10 $W \cdot cm^{-2}$ or beam power above 0.5 W) class 3b lasers may pose a hazard under some conditions.

High-pressure arc lamps, filament lamps, and capacitor banks of laser systems can pose explosion hazards in addition to laser target materials. When laser system components pose explosion hazards, they should be enclosed in housing that can withstand the maximum explosive pressure. Laser target materials and other elements should also be enclosed or shielded to protect workers when an explosion hazard exists.

Laser Generated Air Contaminants (LGAC's)

LGAC's are fumes, gases, vapors, or other particulates generated from a material coming into contact with a class 3b or 4 laser beam. Composition of the LGAC's can vary and depend mainly on the material, gases present, and the beam irradiance (approximately 10^7 $W \cdot cm^{-2}$ and above). Welding may yield higher concentrations of LGAC's than cutting. Care should be given in medical applications of lasers due to hazards of vaporized tissue plumes that may release plasmas, cell and viral fragments.

MSDS's usually provide useful information on decomposition products of the material, but little information on the biological effects of the actual contaminant. A qualified safety officer should determine what contaminants might be present, their concentrations, effects, and the appropriate control measures, remembering to take industrial hygiene aspects into consideration to comply with the 29 CFR 1910 Subpart Z on threshold limit values (TLV's). Hazards from assist gases should be evaluated also.

Laser Dyes and Solvents

Several dyes that are used as lasing mediums are toxic, carcinogenic, or flammable. Caution must be taken when handling or preparing these chemicals, or operating dye lasers. Laser dyes should be prepared in a fume hood to prevent exposure. Dye pumps and reservoirs should be placed in a secondary containment unit to minimize the threat of leakage. MSDS's shall be made available to all workers that may come into contact with these chemicals. Compliance with the NFPA and NEC is required when flammable liquids (100 mL or more) are present.

Dimethylsulfoxide (DMSO) is a solvent commonly used in laser applications that aids in the transport of dyes through the skin and into the bloodstream. An alternative solvent should be used when possible, but if this is not feasible, gloves should be worn to prevent contact with the solvent.

Compressed Gases

There are risks of exposure to toxic chemicals as well as explosion hazards associated with use of pressure cylinders. Losses can occur due to polymerization, adsorption, or reaction with the cylinder walls; or pressure decreases can cause desorption from the walls to yield a concentration higher than the original concentration.

Gases of different categories should be stored separately according to OSHA and the Compressed Gas Association requirements. Cylinders containing hazardous gases should be labeled, anchored, and isolated from personnel. Procedures for purging gas before disconnection or reconnection should be used. Open cylinders should be protected from the atmosphere and maintained in appropriate exhaust enclosures. Clean regulators made of materials that will not adsorb or react with the cylinder's contents shall be used. Specially

coated aluminum cylinders can be used in place of steel to assure stability of reactive gases.

Radiation

Collateral and plasma radiation (other than that associated with the laser beam itself) may be produced by system components or be generated when focused on a target. Ultraviolet, visible, infrared, microwave, X rays, and radio frequencies are all forms of radiation that may be emitted from the target or system components. The probability of collateral radiation is higher with high-powered equipment, Q-switches, pump lamps, laser discharge tubes, high voltage vacuum tubes, plasma tubes, and even the material-laser induced plasma itself. Radiation emitted from the target and laser system should be investigated and controlled to comply with state and federal regulations, and/or ACGIH standards.

Noise

Noise levels from certain high intensity lasers may reach levels that require controls. Where potential for hearing loss is suspected, an industrial hygienist or one competent in audiometric testing should perform such testing. If the calculated dose exceeds the OSHA action level, a hearing conservation program must be employed.

Waste Disposal

Disposal of contaminated laser-related material should be handled according to local, state, or federal standards.

Injury Prevention

It is the duty of the employer to ensure adequate supervision, training, facilities, equipment, and supplies are available to control potential hazards. Control measures shall be put in place to reduce potential of exposure to laser radiation above the exposure limits during operation, testing, service, maintenance, and modification. The registered user and DSO shall designate control measures and decide when present control measures are no longer sufficient. The DSO may designate a deputy DSO or other person to carry out specific responsibilities and aid in the surveillance of control measures.

HAZARD ASSESSMENT (MPE, NHZ, AND CONTROL AREAS)

An initial survey should be performed which includes assessment of possible non-beam hazards, evaluation of beam hazards, determination of the maximum permissible exposure limit (MPE) and nominal hazard zones (NHZ's) for class 3b and 4 lasers and laser systems with open beam paths. If the laser or laser system has been modified, reclassification should be carried out and hazards reevaluated according to the maximum output available for intended use. The total hazard evaluation should consider the following aspects:

- the laser system's capability to cause injury or interfere with task performance
- the environment in which the laser is used
- the personnel who may use or be exposed to laser radiation

Usually field measurements for laser radiation are not necessary, and potential laser hazards can be analyzed by numerical methods. Only those trained in laser safety, optical engineering, or physics are suited to perform detailed hazard classifications. In some instances, the registered user or DSO may not have these qualifications, and should assign

this responsibility to someone trained in this area that can provide technical expertise to assure accuracy of calculations and risk assessments. Errors in analysis could result in insufficient controls resulting in exposure to hazardous conditions.

When there is potential for exposure from partially enclosed or exposed beam paths from class 3b and 4 lasers, a laser control area should be proposed. Once the NHZ is determined and the control area is established, controls (such as warning signs, lights, signals, or curtains) should be put in place to warn those in the vicinity and keep transmission outdoors separated from the indoor area. Personnel within the control area should also be protected from hazardous laser radiation levels.

ENGINEERING CONTROLS

Engineering controls are physical or mechanical controls that are part of the laser itself, or involve a change in the laser that will reduce/control the hazard it poses and/or its classification. They should be the primary means of protection before administrative controls, procedural controls, and personal protective equipment. Engineering controls can include, but are not limited to interlocks, shutters, alarms, substitution, process change/isolation, source modification, and ventilation. Lasers manufactured in compliance with the Federal Laser Products and Performance Standard (FLPPS) will only have those engineering controls required by FLPPS. All other engineering controls will be supplied by the manufacturer or designated by the registered user or DSO.

Enclosed Beam Paths and Protective Housing

Enclosures should be used when possible. A laser or laser system with a fully enclosed beam path fulfills all requirements of a protective housing and no further controls are necessary. When operation of a laser or laser system without the protective housing becomes necessary, the registered user and DSO shall perform a hazard analysis and assign appropriate control measures. Curtains, barriers, shrouds, and beam stops are some alternative controls to use with an open laser system.

Walk in protective housing with embedded class 3b and 4 lasers should have an area warning system that is interlocked with the power supply or laser shutter to prevent exposure above the MPE.

Beam Height

The laser should be set at a height and angle that will minimize the chance of eye exposure to the laser radiation. The laser beam should be set either below seated eye level or above standing eye level (avoid heights between 3.5 and 5.5 feet) when possible.

Restricted Access

Labs and areas containing lasers and laser equipment should have doors that can be shut and locked to avoid accidental exposure to hazardous levels of laser radiation. Doors should be locked and/or warning devices employed when the laser system is in use, and when the registered user is not available.

Interlocks

Class 3b and 4 laser systems should be connected to a remote interlock connector, which in turn is connected to an emergency-disconnect interlock. This will control access to laser

radiation above the MPE. A separate mechanism to prevent access to laser radiation above the MPE when the protective housing is opened should also be used. Protective housing interlocks should not be defeated during operation.

Lockout/Tagout

OSHA 1910.147 applies to lockout/tagout systems for controlling energy release. Lockout/tagout systems are an effective way of safeguarding against accidental start -up of a machine that is supposed to be turned off. Lockout systems use locks to prevent access to the energy-isolating device, and tagout systems use securely fastened signs to warn against reenergizing the equipment. Tagout systems should only be used when lockout systems are not feasible.

Some devices that may be used are chains, locks, tags, wedges, key blocks, adapter pins, and self-locking fasteners. They should be attached in a manner that will hold the isolating device in an "off" position, and substantial enough to prevent inadvertent removal. Only the employee who applied the lockout/tagout device should remove it. The proper lockout procedure sequence for energy control should be followed from preparation for shutdown to device removal.

Lockout/tagout standards do not apply to work on cord and plug connected equipment where unplugging from the energy source will give the employee servicing the equipment exclusive control.

Warning Devices

Warning devices are one way of communicating the presence of a hazard through an audible or visual message. Laser warning signs should be posted at the exterior boundary of a laser controlled area, or entrance to a laser controlled area, and should comply with either ANSI Z535 or IEC 60825-1 design. Warning signs should also be posted for non-beam hazards in the area. Activation of a visual and/or audible warning device can be coupled with emission of laser radiation to warn personnel in the area when the power supply is charged for operation. Sounds should be distinctive and clearly identifiable.

Equipment Labels

All laser equipment shall have appropriate warning labels. Labeling requirements should be in accordance with the FLPPS. Both the housing and control panel should have labels if they are separated by more than two meters, or the housing is removable. Long distance beam conduits containing beams above class 1 should have labels placed at three meter intervals along the outside of the conduit.

Beam Stops, Attenuators, and Beam Termination

Class 3b and 4 laser systems should be provided with a permanently attached beam stops or attenuators to prevent laser radiation in excess of the MPE from escaping the system when output is not required (during warm up). Temporary beam stops can be used in some instances to reduce the level of laser radiation below the MPE.

A safe, fire-resistant, absorbing material with a low diffuse reflection should be used to terminate the beam path of high-power lasers. Backstops should be used behind mirrors to

prevent transmission of laser light during alignment and use. Laser beams should never be directed at windows or doors.

Ventilation and Respiratory Protection

Hazardous vapors, smoke, fumes, and/or dusts can emanate from open cylinders, preparation of dyes and solvents, and LGAC's. Biological agents may also emanate from lasing of tissues. Adequate ventilation systems should be used when contaminants associated with laser use have potential to become hazardous or rise above the permissible exposure limit (PEL). Enclosed hoods should be used where possible, with capture velocity appropriate for the type of contaminants present (vapors, smoke, fumes, dusts). Ball mouth or flanged hoods, and appropriate filters should be used with local exhaust to avoid recirculation of the contaminants.

OSHA 29 CFR 1910.1000-1910.1450 regulates the occupational exposure to toxic and hazardous substances. Respiratory protection may be used to control brief exposures or as a temporary control measure. However, if this method is used, a respiratory protection program shall be established and comply with OSHA 29 CFR 1910.134.

PERSONAL PROTECTIVE EQUIPMENT

Personal protective equipment for laser use is required where administrative, procedural, and engineering controls are insufficient to prevent exposures above the MPE. A total hazard evaluation should be performed by the registered user or DSO (or a designated individual who is qualified to perform laser hazard evaluations according to the training specifications outlined in the training section of this manual) to establish what hazards are present, NHZ's, and the equipment needed to provide adequate protection. Equipment should be selected to withstand direct or scattered beams, taking the damage threshold into account (should be greater than 10 seconds). Choice of personal protective equipment includes beam shields, barriers, windows, goggles, spectacles, face shields, attenuating clothing and gloves, creams, and curtains. All protective equipment should be labeled with the optical density, wavelength, threshold limit, and exposure time where applicable.

Barriers, curtains, and windows can be used to block or reduce the radiation transmitted to a level below the MPE. The barrier used should be within the NHZ of class 3b or 4 lasers, and shall have the appropriate filter or barrier screen. Flammability, potential for decomposition, threshold limit, and exposure time should be taken into consideration to assure that the material is not combustible, will not release LGAC's, and can withstand beam radiation.

Potential for skin exposure generally occurs with ultraviolet (UV) lasers and welding operations. Skin protection shall be provided when repeated exposure above the MPE levels for skin is probable. Skin covers like tightly woven fabrics, lab coats, and opaque gloves offer good protection. Laundered fabrics and fabrics with continuous films demonstrate good attenuation. Flame retardant materials should be worn when using class 4 lasers. Sun blocks offer great protection in the UV and visible regions, and possibly into the infrared (IR). Sunscreen creams free of photosensitizing ingredients can be used also, but may not be adequate for use with actinic UV radiation.

Eye protection is required for class 2 and 3a lasers where intentional long term exposures are likely, and for class 3b and 4 lasers where other controls are inadequate or not feasible. Eye protection should also be provided for welding processes to protect from laser-induced plasmas. Equipment of the appropriate optical density (OD) should be selected for the corresponding wavelength. The OD and MPE should be anticipated for all viewing angles and wavelengths, although adequate visibility should be achieved without reducing the necessary OD, and warning/indicator lights should still be visible. Alternative methods of protection (such as multi-length protection or indirect viewing) should be used when operating tunable lasers or lasers of multiple wavelengths.

Periodic cleaning and inspection of protective eyewear shall be done to ensure equipment is in good condition. The manufacturer's cleaning instructions should be followed to prevent damage. The following should also be examined when inspecting eyewear:

- pitting, cracking, or discoloration of the attenuation material
- mechanical integrity of the frame
- leaks and coating damage

Administrative and Procedural Controls

MEDICAL SURVEILLANCE

Laser personnel frequently working with class 3b and 4 lasers should undergo an ophthalmologic examination prior to using the lasers. The exam should include ocular history, visual acuity, Amsler Grid Test or macular function test, and color vision. Workers with medical conditions noted in the ocular history exam should be evaluated carefully for potential chronic exposure. Results not deemed satisfactory will require identification of the cause by examination of the ocular fundus, or other means as considered appropriate by the medical or optometric examiner. Employment should not be denied, unless chronic viewing of these wavelengths is required.

Employees that suspect or have acquired an eye injury should see an ophthalmologist. If symptoms such as after images, burning of the eye, difficulty in detecting blue or green colors, or an audible "pop" at time of exposure occurs, they must seek medical attention immediately. Medical exams should be repeated upon suspicion of exposure or injury; however periodic and exit exams are not required.

Skin examinations are not required for pre-placement, but are recommended for those working with UV lasers, for personnel with a history of photosensitivity, and for those using photosensitizing drugs. Employees with dermatological abnormalities or health conditions that would make them more susceptible to skin reactions from laser radiation exposure should obtain physician approval prior to work, and use skin protection while operating lasers. Employees that suffer skin injuries during employment should see a physician.

Results from the examination should be discussed with the employee. Non-personally identifiable records should be made available to epidemiologists, medical consultants and

physicians upon request. Medical surveillance records should be retained for all employees three years following termination of employment.

TRAINING

Training is required for employees using class 3b, 4 lasers, and lasers with embedded class 4 lasers. Laser users and personnel working around lasers shall have access to laser safety literature, manuals, standard operating procedures (SOP's), and shall undergo awareness training. Refresher training and performance-based training should be implemented as deemed necessary by the registered user and DSO, depending on the hazard evaluation criteria. Refresher training should be a general overview of laser safety or an abbreviated form of the original training. Both the owner and the DSO should keep documentation of training for three years following termination of employment. Training classes should be comprehensive, cover all applicable topics, and be taught by someone competent in laser use, laser safety concepts, and laser safety standards. The University of Georgia Environmental Safety Division should approve those who conduct laser training as well as the means of conducting the training.

Training for users of class 1, 2, and 3a lasers should include:

- explanation of a laser
- comparison of laser light to ordinary light
- explanation of laser classification and effects
- cautioning against intentional staring
- education against misuse

Training for class 3b and 4 laser use can be general or application based, but shall include:

- fundamentals of laser operation
- bio-effects of laser radiation
- relations of specular and diffuse reflections
- non-radiation hazards of lasers
- ionizing radiation hazards (where applicable)
- laser and laser system classification
- control measures
- lockout/tagout procedures
- overall management and employee responsibilities
- medical surveillance practices
- electrical safety and/or CPR for those exposed to high voltages and potentially lethal currents

Qualified safety officers or other individuals responsible for the laser safety program (hazard evaluation and control measures) should have a thorough knowledge of the topics listed above, as well as:

- laser terminology
- types of lasers, wavelengths, pulse shapes, modes, power/energy
- basic radiometric units and measurement devices
- MPE levels for eye and skin under all conditions

- laser hazard evaluations, range equations, and other calculations applicable to lasers under their jurisdiction

Training on potential hazards, control measures, applicable standards, medical surveillance, and any other pertinent information should be provided to the safety officer, unless they are provided adequate consultative services. The training should be applicable to at least the highest class of laser under their jurisdiction.

PERIODIC SURVEYS

Periodic surveys should be conducted to ensure appropriate safety precautions are established and followed. Surveys should also be performed where a change to the laser or laser system might change the NHZ and MPE levels significantly.

INJURY REPORTING AND RECORD KEEPING

The DSO and registered user of the laser or laser system should keep records of servicing, accidents, exposures, investigations, medical evaluations, and training. All personnel records should be maintained locally for at least three years following termination of employment, and should be available for inspection at any time. Employers are required to provide injury/illness reports to government representatives, employees, former employees and their designated representatives. The registered user must report any occupational injuries or illnesses resulting from laser use to the DSO and ESD, especially if they result in one or more of the following:

- suspected ocular exposure to levels above the MPE
- skin burns
- medical treatment beyond in-house first aid
- restricted motion or work tasks
- one or more days away from work
- transfer to another job
- loss of consciousness
- death
- any other condition listed in Appendix B of the rule

EXPOSURE/INJURY INVESTIGATION

The purpose of injury investigation is to find the cause of an accident and prevent its reoccurrence. In the case of an accident or exposure, the DSO, ESD, and/or a designated safety and health professional shall be notified at once so that an investigation can be done promptly. The investigation should begin as soon as emergency procedures have been accomplished and the situation is under control. The accident scene should be isolated, evidence recorded, and witnesses interviewed to gather information about details leading to the accident.

CONTROL OF ACQUISITION

The Environmental Safety Division reserves the right to require prior notification of purchase of lasers and laser systems. All lasers and laser systems must be registered with the Department of Human Resources within thirty days after the date of acquisition. Users that permanently discontinue operation or permanently dispose of their lasers or laser systems must also notify the Department of Human Resources within thirty days. To

comply with Chapter 290-5-27, registration and discontinuance forms should be sent within ten days to allow for proper registration of the laser (or blanket registration of the laser system) or report of discontinuance.

LASER DEMONSTRATIONS

Laser demonstrations can be dangerous, and are strongly discouraged. Therefore appropriate controls shall be exercised where lasers are used for demonstration, artistic display, entertainment, or other uses where viewers are members of the general public. Approval of laser shows on campus for the general public is up to the discretion of ESD upon consideration of ANSI 136.6 and FAA Order 7400.2. Spectators should not be permitted within a laser-controlled area containing class 3b and/or 4 lasers before the following conditions are met:

- Approval has been obtained from the registered user
- Degree of hazards and avoidance procedures have been explained
- Appropriate protective measures have been taken

SPECIAL/ALTERNATE CONTROLS (INVISIBLE LASERS, LASER LIGHT SHOWS, OUTDOOR CONTROL MEASURES)

ESD and/or a qualified safety officer may approve alternate controls to replace personal protective equipment, engineering, administrative, or procedural controls on a case-by-case basis. The new controls must present adequate or equivalent protection. Personnel affected by the new control measures should be properly trained on new laser safety and operation issues presented by the alteration.

ALIGNMENT PROCEDURES

Alignment procedures should be performed in an isolated area in a manner that prevents ocular exposure above the MPE. During alignment, the safety shutter should be closed, beam power should be as low as practical or alignment should be performed using an alignment laser (low power visible laser used for path simulation). Only diffuse viewing should be viewed, and performed only when wearing eyewear appropriate for the laser. Invisible beams can be viewed using non-laminated viewing cards/eyewear with diffusing finishes, and IR beams can be viewed with infrared viewers/scopes.

A temporary beam attenuator can be placed over the aperture to reduce laser radiation to levels at or below the MPE. Written SOP's outlining alignment methods should be approved by a qualified safety officer for Class 3b and 4 laser systems (and systems with embedded class 3b and 4 lasers when alignment allows access to laser radiation).

STANDARD OPERATING PROCEDURES (SOP'S) AND EMERGENCY PROCEDURES

Standard operating procedures are required whenever there is potential for exposure to hazardous levels of laser radiation, and should be posted near the laser area. ESD and/or a qualified safety officer should approve individual written standard operating, maintenance, service, and alignment procedures for class 3b and 4 laser systems of laser systems that are not considered 'manufactured', and those laser systems which have been modified significantly enough to introduce new safety issues. All other laser systems should come with an SOP from the manufacturer. The owner, for reference of the operators and service

personnel, shall maintain these with the laser equipment to improve safety and eliminate uncertainty among laser area employees, and update them annually (if changes have been made).

LASER MODIFICATION/SERVICING/MAINTENANCE

A qualified safety officer may reclassify a laser or laser system that has been modified according to the provisions and requirements in ANSI Z136.1. In addition to the reclassification requirement, the laser or laser system may require recertification and compliance with FLPPS requirements.

Potential for hazardous exposure to laser radiation may exist during servicing of lasers with enclosed beam paths that requires removal of the protective housing. Service and maintenance personnel should comply with the appropriate control measures if the procedure may expose personnel to laser radiation levels above the MPE. A temporary laser control area should also be established where service activities require access to an embedded class 4 laser.

OSHA 1910.147 applies to the control of energy during servicing or maintenance of equipment and should be followed to prevent accidents. Proper lockout/tagout methods should be used to avoid unexpected activation of the laser system during maintenance/service procedures. Systems with stored or residual energy (i.e. capacitors) should be properly dissipated and discharged (by grounding) and rendered safe before beginning work.

Definitions

ACGIH – American Conference of Governmental Industrial Hygienists

Actinic radiation – Photochemically active radiation.

Administrative controls – Controls implemented by the governing entity to enforce and encourage safe behaviors and procedures.

ANSI – American National Standards Institute

Ancillary hazards – Secondary hazards arising from equipment associated with the laser beam, lasing media, or the laser beam itself.

Aperture – Opening through which the laser beam passes.

Assist gases – Gasses used to aid the laser beam in generation of a specific end product.

Attenuator – Device that reduces the intensity of, or stops the laser beam by absorbing or scattering the radiant energy.

Average power - total energy of an exposure divided by the duration of the exposure.

Aversion response - Action, such as closing of the eye or movement of the head, to avoid exposure to laser light (about .25).

Cataract – Opacity of the lens or capsule of the eye, resulting in impairment of vision.

Collateral radiation – Radiation other than that associated with the laser beam itself.

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

Diffuse reflection – Change in the spatial distribution of a beam's irradiance when it is reflected in many directions by a surface.

Dimethylsulfoxide (DMSO) – A toxic solvent often used in lasing applications.

Embedded laser - A laser with an assigned class number higher than the inherent capability of the laser system in which it is incorporated, where the system's lower classification is the result of engineering features which limits the accessible emission.

Engineering controls – Mechanical controls integrated into the laser or laser system to reduce or eliminate exposure hazards.

Erythema – Redness of the skin.

FLPPS – Federal Laser Products and Performance Standards

Fundus – Back of the eye.

IEC – International Electrotechnical Commission

Infrared (IR) light – Range of the spectrum (between red and microwave) with invisible wavelengths (from about 700 nm to 1 mm).

Interlock – A mechanism or device that prevents operation of a laser or laser system without first defeating it.

Intra-beam viewing – Viewing of a laser while all or part of the beam is directed into the eye.

Interlock – A device that prevents operation of the laser beam without directly enabling capacity.

Irradiance – Emission of light.

JCAHO – Joint Commission on Accreditation of Healthcare Organizations

LASER – Light Amplified by Stimulated Emission of Radiation. Device that emits laser radiation.

Laser beam – A highly collimated, coherent, and monochromatic emission of light.

Laser 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.

Laser generated air contaminants (LGAC) – A plume of smoke, fumes, or gases produced from interaction of the laser beam with a material, substance, or tissue.

Laser radiation – Optical radiation that is monochromatic and demonstrates other properties such as coherence and low divergence.

Laser System – An assembly of electrical, mechanical, and/or optical components that includes at least one laser.

Lockout device – A device that uses a lock to hold an energy-isolating device in the "off" position.

Lockout/tagout – A safety program which uses the placement of lockout and tagout devices on an energy isolating device to prevent accidental startup of equipment during maintenance or service.

Macula – A minute yellowish area near the center of the retina where vision is most acute.

Maintenance - Performance of those adjustments or procedures specified in user information provided by the manufacturer with the laser or laser system, to ensure the intended performance of the product.

Material safety data sheets (MSDS) – Tables that offer health hazard information such as toxicity, safety and handling considerations for chemicals. Infectious dose, viability (including decontamination), medical information, laboratory hazard, recommended precautions, handling information, and spill procedures are also available for biological and infectious agents.

Maximum permissible exposure (MPE) - The maximum level of laser radiation to which a human can be exposed without adverse biological effects to the eye or skin.

NEC – National Electric Code

NFPA – National Fire Protection Association

Nominal hazard zone (NHZ) – The zone around the laser where the beam intensity (from direct, reflected, or scattered beams) exceeds the maximum permissible exposure limit.

Optical density (OD) – The ability of a material to reduce laser energy of a specific wavelength to a safe level below the MPE.

OSHA – Occupational Safety and Health Association

Output – Power emitted by a laser. Usually expressed in watts for continuous wave lasers, and joules per pulse in pulsed lasers.

PEL – Permissible Exposure Limit

Performance-based training – Training that is repeated by an employee due to a demonstrated lack of competence in laser safety issues.

Photo-keratitis – Inflammation of the cornea due to radiant energy exposure.

Photosensitization – Inducing photosensitivity by repeated exposure to radiant energy.

Plasma – produced when laser energy interacts with a target to form a stream of charged particles. It is affected by a magnetic field, exhibits properties of a gas, and is a good conductor.

PPE – Personal Protective Equipment

Protective housing – An enclosure surrounding the laser or laser system that will prevent access to laser radiation above the MPE.

Pulse duration – Duration of a pulsed laser flash, usually measured between half-peak-power points on the leading and trailing edges of the pulse.

Pulsed laser - A laser which delivers its energy in the form of a single pulse or a train of pulses. The duration of a pulse is regarded to be < 0.25 s.

Pulse repetition frequency (PRF) - The number of pulses transmitted per second.

Radiation – Emission of energy in the form of rays or waves.

Radiant exposure – Surface density of the radiant energy received in the form of radiation.

Radiant power (Flux) – Power emitted, transferred or received in the form of radiation.

Repetitively pulsed laser - A laser with multiple pulses of radiant energy occurring in sequence with a PRF > 1 Hz.

Service - The performance of those procedures or adjustments described in the manufacturer's service instruction which may affect any aspect of the performance of the laser or laser system. These are usually performed by qualified technical personnel provided by the manufacturer or other service companies.

SOP – Standard Operating Procedures

Specular reflection – Occurs when a beam is reflected off a mirror-like surface.

Standard – A document, established by consensus and approved by a recognized body that provides rules, guidelines, or characteristics for activities or their results and is aimed at achieving an optimal degree of order for a specific use.

Sun Block/sunscreen – Preparation used to filter out UV rays to protect the skin from burns.

Tagout device – A warning device that can be securely fastened to an energy-isolating device to indicate that the energy isolating device and equipment may not be operated until the tagout device is removed.

Threshold limit values (TLV) – degree of exposure to which one may be exposed to laser radiation without risk of adverse effects.

Threshold limit (of PPE) – degree of exposure to which the personal protective equipment can stand before degradation occurs.

Tunable laser – Laser adjustable over several wavelengths of light or degrees of power.

Ultraviolet (UV) Light – Invisible radiation wavelengths between Xray and violet light (from about 200 to 380nm).

Visible light – Light within the visible wavelengths of the spectrum (400 to 700nm).

Wavelength – Distance between two peaks of a periodic wave.

X rays – High-energy photons with wavelengths between .01 to 10 nanometers.