Information for Operational Standard Operating Procedure

The following is not a written procedure but includes laser and laser safety information that may be selected to be integrated into a standard operating procedure for an operational unit using Class 3B or 4 lasers or Class 1 laser products with embedded Class 3B or 4 lasers that will be serviced in place.

Laser Identification

1. Specific Location – Sufficient for identification by emergency responders (e.g., building, aisle designation, column number/room number).

2. Owner and contact information – Specify contact for all hours the laser is operational.

3. Type – Usually the name of the lasing medium for each laser in use.

4. Wavelength(s) – List all accessible wavelengths; if ultra-broadband output is possible, give the wavelength boundaries and the most commonly used wavelengths.

5. Pulsed or continuous wave – Dictates what output parameters are required besides wavelength.

6. Output parameters
    - a. Pulsed: energy per pulse, pulse duration, pulse repetition frequency
    - b. Continuous wave: average radiant power
    - c. Raw beam: full angle beam divergence, emergent beam diameter
    - d. Focused beam: beam spot size incident on finishing lens, focal length of finishing lens
    - e. Diffuse reflection: Reflectance of surface (wavelength dependent)

Emergency Response

1. Employees who are accidentally exposed to laser radiation must call the emergency number (911) to report then proceed directly to _____(state location)_____.

2. Employees who are accidentally exposed to optics cleaning solvents must proceed directly to the safety shower or eyewash, remove any affected clothing, and rinse/flush for 15 minutes or the time period specified on the material safety data sheet.

3. Employees who are accidentally exposed to fluorine, must proceed directly to the safety show or eyewash, remove any affected clothing, and rinse/flush for 30 minutes. Call the emergency number (911) and follow directions for repeated application of calcium gluconate gel to the affected skin area.

4. If the laser beam ignites materials, proceed to the nearest fire extinguisher and use per training. Call the emergency number (911) for assistance.

5. If there is a sudden release of compressed gas, give notification and evacuate the area, closing all doors. Call the emergency number (911) for assistance.

Personnel Requirements

1. Personnel who operate, maintain, or service lasers must be authorized by management and the laser safety officer.

2. Authorization requirements include initial laser safety awareness training, refresher training (as applicable), and __(specify other requirements)_____.

3. All employees who operate, maintain, or service lasers must take the laser safety awareness training course and receive hands-on training from departmental personnel who are authorized to provide this training. Employees will use lasers only for tasks for which they are authorized.

4. Employees who are accidentally exposed to laser radiation or non-beam hazards must notify emergency response and departmental management and proceed directly _________(give direction, here)________.

5. Employees will follow all written safe operating procedures, alignment procedures, and safe work practices when working with lasers.

6. Employees will handle, store, and clean laser protective eyewear as the important safety system which it is.

Hazard Overview

Select the most appropriate information from the following paragraphs.

Laser Radiation

1. Laser radiation is a known and recognized hazardous physical agent that is capable of injuring the eyes and skin. The eyes are more vulnerable than the skin, because of the potential for permanent debilitation. The skin is at greater risk of exposure because of its large surface area.

2. The structure of the eye at risk of laser-induced injury is determined by the wavelength and irradiance (or radiant exposure) of the laser radiation, and the exposure duration. In general, ultraviolet (UV) and far infrared (IR) laser beams target the cornea of the eye. Visible and IR-A wavelengths, 400 to 1400 nm, target the retina. The two spectral regions are often combined and called the retinal hazard region.

3. Retinal injury may include minimal threshold lesions that may have no effect on vision if the injury lies outside the macula, or may manifest as blind spots in vision with decreased visual acuity is the macula/fovea is damaged. Significant injury from overexposure to pulsed laser radiation may lead to disruption of the retinal layers and the capillary bed at the bottom of the retina leading to hemorrhage. This form of retinal injury may result in significant reduction in visual acuity in the affected eye.

4. Transmission within the eye decreases as wavelength approaches the boundaries of the retinal hazard region (i.e., 400 and 1400 nm). In general, there is a transition region on either side of the retinal hazard region (violet/blue light and UV-A as well as IR-A and IR-B) where there is a transition to shallow penetration depth from deeper penetration depth. Here, posterior structures of the eye such as the iris or lens, as well as the cornea, are increasingly at risk of injury.

5. Corneal injury (from IR-B, IR-C, and UV radiation) results in damage to living cells. The injury may be a painful burn which requires medical intervention and often temporary debilitation of a few days. If the exposure is to UV radiation, the damage may be similar to that experienced by arc welders, called welder's flash. In the most severe cases of corneal injury, the damage may involve painful ulceration requiring medical intervention.

6. The skin is inhomogeneous and may reflect, scatter, or absorb laser radiation. Skin damage is determined by the irradiance (or radiant exposure) of the beam, the duration of exposure, and the heat flow from the absorbing site. In general, UV-C radiation is absorbed topically, while UV-B and UV-A radiation may penetrate more deeply into tissue. Visible and IR-A radiation penetrate more deeply still, with the greatest penetration depth occurring in the IR-A spectral region. Penetration depth decreases into the IR-B spectral region

while optical radiation is absorbed topically in the IR-C region. Acute, laser-induced skin injury is painful and may result in the formation of scar tissue, but usually is non-debilitating.

7. Effects to the eye and skin may be thermal or photochemical in nature. UV radiation produces health effects predominantly by photochemical reactions, although thermal effects occur as the wavelengths lengthen and approach the visible spectral region. Relatively lengthy (approximately 10-15 sec or greater) exposure to short-wavelength blue and green light produce photochemical effects to the retinal tissue of the eye, but have not been observed to do so with the skin. The long-wavelength visible radiations (yellow, orange, red) and the IR wavelengths produce thermal effects to both eyes and skin.

8. If the laser radiation is delivered in very short pulse durations (nanoseconds, picoseconds, femtoseconds) as occur in Q-switched and mode-locked pulses, it is possible that other effects may occur. These include effects associated with acoustic phenomenon and shock waves, as well as self focusing of the beam within the eye and ablation of tissue.

9. In general, UV radiation is the most hazardous form of optical radiation. This is because of the potential for both short-term and long-term health effects. Short-term effects include corneal damage and skin burns. Long-term effects from work-place exposures may include a contribution to the UV dose necessary for cataract formation. Skin effects include aging and cancer. The U.S. National Toxicology Program classifies broad-spectrum UV radiation as a “known human carcinogen.” The three UV regions, UV-A, -B, and –C, are classified in the category “reasonably anticipated to be known human carcinogens.”

10. The ocular exposure limits are quite low for visible and IR-A radiation because of the seriousness of injury to the retina. Retinal injury is often permanent and debilitating, especially for exposures well above minimal damage thresholds.

Non-beam Hazards

1. Non-beam hazards may pose a serious risk of immediate injury or the potential for long-term effects. For example, immediate injury such as electrocution, shock or thermal burns may be the result of electrical contact with energized circuit components or physically hot components. Long-term effects during laser welding on stainless steel could involve chronic exposure to laser generated airborne contaminants and/or plasma radiation.

2. Collateral radiation is non-laser radiation that is generated by the normal operation of the laser or laser system. Collateral radiation may include x-

radiation, UV, visible, IR, and radio-frequency radiation (RFR), as well as power frequency fields. The type of radiation(s) generated by the laser system will depend upon the function of the laser, the potential difference across circuit components, the type of energy pump, and the application. Material processing lasers may produce a type of collateral radiation, called plasma radiation, when the beam interacts with matter, primarily metals. Possible sources of collateral radiation include, but are not limited to

x-radiation	Thyratron switches: some carbon dioxide & Excimer lasers
UV radiation	Flash lamps, plasma tubes, material processing
Visible radiation	Same as UV radiation
IR	Same as UV radiation
RFR	Energy pump for some carbon dioxide lasers
Power-frequency	Power supplies, electrical wiring for all AC lasers

3. The same interaction that produces plasma radiation may liberate chemical agents into the air. If uncoated metal is the target, the agents are usually oxides of the base materials. Some metals and alloys involved in welding, cutting, drilling can produce hazardous air contaminants. For example, oxides of nickel and chromium can be generated by laser processing of stainless steel. For plastics and other organics (e.g., wood or paper products), there is often a large number of chemical agents that are generated by chemical reactions that occur immediately following absorption of the laser radiation by the base material. Some of these materials may be known or suspect carcinogenic agents such as benzene, formaldehyde and polycyclic aromatic hydrocarbons.

4. Class 4 laser beams have sufficient energy to cause fires in ignitable materials including system components (e.g., bellows beam delivery enclosure) and target materials. Class 3B lasers may have sufficient energy to ignite flammable gas-rich or dust-laden atmospheres. Laser components, such as flash lamps, or laser-beam target materials can explode.

Environmental Hazards

1. Laser radiation may be an environmental hazard if the beam is allowed propagate outdoors without appropriate control measures in place. In some cases, it may be necessary to contact the Federal Aviation Administration or the Air Force Space Command. (See Appendix A of ANSI Z136.6, *American National Standard for Safe Use of Lasers Outdoors*, for specific guidance.)

2. Some components of lasers and laser systems may need to be identified and removed for reclamation prior to disposal of the laser. This could include, for example, bound arsenic in laser diodes. Other lasers may contain valuable

materials that will be reclaimed and recycled. An example would be the gold or silver plating on reflective components in some neodymium:YAG lasers or copper mirrors in carbon dioxide lasers.

3. Certain air contaminants generated during material processing may be regulated and must be included in the applicable state and/or local government air permits. Check with the appropriate state agency for guidance.

Control Measures

1. All employees or visitors who operate, maintain or service the laser must be authorized to do so by management and the laser safety officer.

2. Remove all reflective and electrically conductive materials from hands, arms, neck and shirt pockets when working with lasers or components of laser systems. Additionally, remove neckties and secure loose clothing.

3. Use materials that create diffuse reflections in and around the beam path and minimize the potential for specular reflections. This includes devices that are fixed in position and devices that are introduced under hand control.

4. Operate the laser with as much of the beam path enclosed as practical.

5. Do not direct the beam toward doors or windows or locate the beam at eye level for seated or standing individuals.

6. Computer work stations should be isolated from the beam. If computer work stations must be located around an open-beam application, orient the screen to minimize the potential for reflection from the glass face (e.g., with the face at a right angle to the beam).

7. Use ANSI-type "Danger" warning signs at the entryway where open-beam Class 3B and 4 lasers are in use.

8. Open-beam Class 3B and Class 4 lasers must be used within a laser controlled area. This requires that ____(description of entryway controls)_____________.

9. Laser protective eyewear used during operation of the laser must be marked with the required level of optical density at the operational power of the laser.

10. Laser protective eyewear must not be stored on work surfaces near lasers or other forms of radiant energy. Laser protective eyewear must be stored

where specified by management in a manner that keeps it clean and free from exposure to agents that may damage them. Eyewear must be cleaned periodically using the instructions provided by the manufacturer.

11. When the laser is serviced, it is necessary for the authorized service personnel to override the safety interlock switches and to work on Class-4 levels of laser radiation. This must be done within a temporary laser controlled area. To establish this area, the immediate work place around the laser is isolated with a laser protective screen/curtain placarded with the "Notice" warning sign. Matte-black tools must be used to minimize the potential for a specular reflection of the beam. Laser protective eyewear of the appropriate wavelength and optical density must be used by service personnel when the laser is operational and guards have been removed allowing beam access.

Beam Alignment Practices

1. Estimates are that approximately one-third of all accidental exposures to laser radiation and 60 to 70% of laboratory accidents occur during beam alignment. Hence, due consideration must be given to work planning, work practices, and control measures necessary to perform beam alignments safely.

2. Follow the alignment procedure specified in the manufacturer's user's manual. Where it is necessary to deviate from this procedure, it is indicated in the departmental alignment procedure.

3. Beam alignments must be performed only by personnel who have specifically authorized by management to perform these tasks.

4. Isolate the area and place the appropriate placard at all entryways. Ensure that all windows and viewing ports are covered with the appropriate material.

5. Locate all necessary apparatus and articles necessary to perform the alignment tasks efficiently and safely in the immediate area.

6. Reduce the radiant power or radiant energy of the beam as low as practical to minimize the potential for overexposure during alignment activities.

7. Where practical, use low-power visible beam lasers for path simulation for high-power visible beam lasers and UV and IR lasers.

8. Perform the coarse alignment with the laser switched off or with the beam attenuator closed. Ensure that all optomechanical mounts are fastened securely.

9. Use matte-black finish tools to minimize the potential for specular reflections.

10. Place tools and other equipment on a cart or side bench to minimize the potential of housekeeping or clutter contributing to an accidental exposure.

11. Do not elevate beams, keeping them in a single plane near the surface of the optical table, whenever possible.

12 Close the beam shutter or use beam blocks when it is necessary to reach into or across the beam path during alignment activities.

13. View only diffuse reflections of the beam using viewing aids such as phosphor viewing cards, ceramic disks, or paper stock (e.g., business cards or 3x5 cards). Where appropriate, use other indirect viewing devices such thermal paper and electronic viewers for the UV and IR spectral regions and CCTV for visible wavelengths.

14 Wear the appropriate laser protective eyewear with respect to wavelength and optical density. If the procedure requires the changing of laser protective eyewear because alignment must be done with multiple wavelengths or beam power is changed during alignment, insure that this is clearly stated in bold in the written procedure and that all authorized laser personnel are aware of the requirement.

15. If the radiant power is reduced by an external optic such as a neutral density filter, variable attenuator, or a beam splitter, locate the optic as close as practical to the output aperture of the laser. For reflective filters, direct the reflected portion of the beam into a beam dump made of the appropriate material and located as close as practical to the filter.

16. Determine the location of any stray or errant beams including reflections from optics and beam transmission through mirrors. Beam blocks or stops should be used at these locations to ensure that accidental exposure does not occur.