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Safety, Health, and Environmental Standard

Title: **LASERS**

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The provisions and requirements of this standard are mandatory for use by all personnel engaged in work tasks necessary to fulfill the AEDC mission. Please contact your safety, industrial health and/or environmental representative for clarification or questions regarding this standard.

Approved:

Contractor/ATA Director
Safety and Health Group

Air Force Functional Chief

Record of Review/Revision

(Current revisions are highlighted in yellow and marked with a vertical line in the right margin.)

Date/POC	Description
01/25/13	Added NFAC supplement; no other change.
04/02/12 Nikodym/Peters	Updated Work Order Management Coordination code: RREQLA corrected to RREQSA.
08/02/11 S. Nikodym	Minor administrative edits and reformatting throughout the document; revisions to Sections 3.0 Definitions, 4.1 General Requirements for All Lasers, 4.2 Additional Requirements for Class 3B and Class 4 Lasers and Laser Systems, 4.5 Medical Surveillance Requirements, 4.6 Responsibilities, 5.0 Training Requirements, and 7.0 References; and minor revisions into Annexes A, C, D, and E. Added Annex F.
06/30/07 R. Jones	Complete re-write of the Standard to incorporate recent changes to AFOSH 48-139 and ANSI Z136.1 – 2007. Read entire standard. Comments provided by TSgt Brian Fair incorporated 10/15/07.
09/15/2005 M. Frederick	Reviewed; administrative changes only: added uncontrolled copy statement; listed titles of references
07/02/2003 R. Everett	Revised to include new format and incorporate AFOSH standard 48-139 as a primary reference.

Safety, Health, and Environmental Standard

LASERS

1.0 INTRODUCTION/SCOPE/APPLICABILITY

1.1 Introduction – This standard identifies a practical means of classifying lasers and laser systems according to their relative hazards and specifies appropriate controls for each classification.

1.2 Scope – Laser light for purposes of this standard includes wavelengths from 180 to 1,000,000 nanometers (nm) which includes the ultraviolet, visible, and infrared regions of the electromagnetic spectrum.

1.3 Applicability – This standard applies to the possession and/or use of all lasers and laser systems throughout facilities operated or managed by AEDC.

2.0 BASIC HAZARDS/HUMAN FACTORS

Lasers produce radiant energy by stimulated emission. The resulting beam of light is nearly monochromatic in wavelength, travels in phase, and has a relatively small tendency to spread through distance. A resulting beam can emerge with a large power/energy density. Light produced by lasers can be visible or invisible. Visible light is predominantly a hazard to the retinal region of the eye. The eye's lens has the ability to focus with a magnification of 100,000 fold. Should a direct or reflected beam enter the eye, the result can lead to vision problems up to and including loss of eyesight. Invisible beams can also damage vision, but the primary mode of damage is through heating of fluids and tissue which compose the eye. Higher powered lasers can also damage the skin.

Ancillary hazards in addition to the primary beam of light include the following:

- Shock, heating, and ignition of flammable materials by electricity
- Collateral radiation in the form of x-rays, ultraviolet/visible/infrared light, microwave and radio-frequency radiation produced by components such as power supplies, discharge lamps, and plasma tubes
- Explosion hazards such as high-pressure arc/filament lamps, capacitor banks, target materials, or laser reactants
- Toxic, noxious, or cancer-causing air contaminants generated by the lasers' interaction with matter
- Chemical and mechanical hazards from low and high pressure compressed gases (i.e., fluorine, chlorine, hydrogen fluoride, hydrogen chloride)
- Chemical hazards associated with many of the dyes and solvents used in laser applications

3.0 DEFINITIONS

Accessible emission limit (AEL) – The maximum accessible emission level permitted by 21 CFR Part 1040 within a particular laser hazard class. The AEL is expressed in watts for continuous wave lasers and joules for pulsed lasers.

Accessible laser radiation – Laser radiation to which the human eye or skin may be exposed for the condition (operation, maintenance or service) specified.

American National Standard for Safe Use of Lasers (ANSI Z136.1-2007) – Document providing guidance for the safe use of lasers and laser systems by defining control measures for each of four laser classifications. AEDC has adopted this standard as a minimum standard for laser safety.

Authorized personnel (AP) – Individuals approved by the responsible individual to install, operate, maintain, or service laser equipment.

Average power – The total energy in an exposure or emission divided by the duration of the exposure or emission.

Aversion response – A physiological response to bright or hazardous light; such as blinking, pupil constriction, looking away, or turning away, that limits the viewer's retinal exposure duration. The tables and calculations in ANSI Z136.1 assume that the aversion response will limit the exposure duration to 0.25 second or less.

Class 1 laser system – Considered to be incapable of producing damaging radiation levels during operation, and is exempt from any control measures or other forms of surveillance.

Class 1M laser system – Considered to be incapable of producing hazardous exposure conditions during normal operation unless the beam is viewed with an optical instrument such as an eye-loupe (diverging beam) or a telescope (collimated beam), and is exempt from any control measures other than to prevent potentially hazardous optically aided viewing; and is exempt from other forms of surveillance.

Class 2 laser system – Emits in the visible portion of the spectrum, and eye protection is normally afforded by the aversion response.

Class 2M laser system – Emits in the visible portion of the spectrum. Eye protection is normally afforded by the aversion response for unaided viewing; however, the system is potentially hazardous if viewed with collecting optics.

Class 3A – The Class designation 3A is no longer used by ANSI. Laser products previously classified as 3A are now Class 3R unless the emergent beam diameter exceeds 7mm, in which case they could be Class 1M or 2M if reassessed. There is no requirement to reassess lasers that were previously classified.

Class 3R laser system – Potentially hazardous under some direct and specular reflection viewing conditions if the eye is appropriately focused and stable, but the probability of an actual injury is small. This laser will not pose a fire hazard or diffuse-reflection hazard.

Class 3B laser system – Potentially hazardous under direct and specular reflection viewing conditions, but is normally not a diffuse reflection or fire hazard.

Class 4 laser system – Hazardous to the eye or skin from the direct beam; may pose a diffuse reflection or fire hazard. This laser may also produce laser generated air contaminants (LGAC) and hazardous plasma radiation.

Collateral radiation - Any electronic radiation, except laser radiation, emitted by a laser or laser system that is physically necessary for its operation.

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

Continuous wave (CW) – The output of a laser operated in a continuous rather than a pulsed mode. For purposes of safety evaluation, a laser operating with a continuous output for a period > 0.25 s is regarded as a CW 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 and related hazards.

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.

Embedded laser – An enclosed 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.

Incidental personnel – Individuals who work in areas where there is a potential for exposure to laser radiation from a Class 3B or Class 4 laser, but who do not operate the laser.

Infrared radiation – Electromagnetic radiation with wavelengths that lie within the range 700 nm to 1,000,000 nm.

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

Laser operator – See “authorized personnel.”

Laser controlled area – See “controlled area.”

Laser hazard class – A system of classification from 1 to 4 based on the hazard of radiation emitted. A Class 1 laser is considered to be incapable of producing damaging radiation levels during operation whereas a Class 4 laser emits a beam with enough energy that even diffuse reflections may be hazardous.

Laser Safety Officer (LSO) – One who has the authority 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 that includes one or more lasers.

Laser worker – A trained and qualified AEDC employee who works regularly with lasers or in a capacity where there is a potential for exposure to the radiation from a Class 3B or Class 4 laser. Persons who work in the general vicinity of laser operations are expected to be restricted from access to open beams and are not considered laser workers.

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

Maximum permissible exposure (MPE) – The level of laser radiation to which a person may be exposed without hazardous effect or adverse biological changes in the eye or skin. MPE is expressed in terms of either radiant exposure (joules/cm^2) or irradiance (watts/cm^2). The criteria for MPE are detailed in Section 8 of ANSI Z136.1.

Nominal hazard zone (NHZ) – The space within which the level of the direct, reflected, or scattered radiation during normal operation exceeds the applicable MPE. (Exposure levels beyond the boundary of the NHZ are below the appropriate MPE level.)

Operating Contractor – The base operating contractor directly accountable to the Air Force for the AEDC mission.

Operation – Performance of a laser or laser system over the full range of its intended functions (normal operation).

Optical density (OD) – Logarithm to the base ten of the reciprocal of the transmittance. The higher the optical density, the lower the transmittance.

Pulsed laser – A laser that 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.

Repetitive pulse laser – A laser with multiple pulses of radiant energy occurring in sequence.

Responsible individual (RI) – A person, appointed by management, to oversee the safe use and operation of lasers or laser systems in the assigned workplace.

Service – The performance of those procedures or adjustments described in the manufacturer's service instructions that 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.

Shall – The word "shall" is to be understood as mandatory.

Should – The word "should" is to be understood as advisory.

Spectator(s) – An individual who wishes to observe or watch a laser or laser system in operation, and who may lack the appropriate laser safety training.

Specular reflection – A mirror-like reflection.

Ultraviolet radiation – Electromagnetic radiation with wavelengths smaller than those of visible radiation; for the purpose of this handbook, 180 to 400 nm.

Visible radiation (light) – Electromagnetic radiation that can be detected by the human eye. This term is commonly used to describe wavelengths that lie in the range 400 to 700 nm.

Visitor(s) – Personnel who are not assigned to work in a laser hazard area, and may not have received initial laser safety training or a laser eye examination, but have a need to enter to perform ancillary tasks such as material delivery, inspections, or servicing and maintenance. (Visitors are sometimes referred to as "incidental workers.")

Wavelength (λ) – The distance between two successive points on a periodic wave which have the same phase. The primary unit of wavelength in this standard is the nanometer (nm) which is 0.000000001 meter.

4.0 REQUIREMENTS/RESPONSIBILITIES

4.1 General Requirements for All Lasers

ANSI Z136.1 American National Standard for Safe Use of Lasers is required for laser operations at AEDC. Persons responsible for laser operations must obtain and use the latest ANSI standard to determine specific technical requirements. Some ANSI requirements applicable to general AEDC operations are re-stated in this section for clarity.

ANSI laser hazard class designations established by the 2007 revision of Z136.1 differ from the 2000 revision, and from those established by the Federal Performance Standards for Light-Emitting Products (FDA-CDRH). Accordingly, equipment labels and area laser hazard warning signs may also differ from those prescribed by the 2007 revision. For consistency at AEDC, the classifications established by ANSI Z136.1 – 2007 shall be used as the basis for determining the appropriate protective measures, training requirements, labels, signs, etc. that apply to specific laser devices. A cross-reference is provided below to assist laser users in determining which requirements should apply when legacy labels and signs exist. See Annex D for further information on laser signs and labels.

Laser Standard Hazard Class Cross-Reference		
FDA-CDRH	**ANSI Z136.1 - 2007**	**ANSI Z136.1 - 2000**
Class I	Class 1	Class 1
No Equivalent[1]	Class 1M	No Equivalent[1]
Class II	Class 2	Class 2
Class IIa	Class 1	Class 2
No Equivalent[1]	Class 2M	No Equivalent[1]
Class IIIa – Caution Label	Class 1M or 2M[2]	Class 3a
Class IIIa – Danger Label	Class 3R	Class 3a
Class IIIb	Class 3B	Class 3b
Class IV	Class 4	Class 4

[1] Use of Magnifying Optics not addressed by FDA-CDRH or Z136.1 - 2000
[2] Class designation will be dependent upon laser's output

4.1.1 Protective Housings (See Annex A)

4.1.1.1 Lasers shall be placed in protective housings whenever practical. When protective housings are not practical, the RI shall perform a hazard analysis to ensure that control measures are implemented to ensure safe operation.

4.1.1.2 Protective housings or service panels enclosing embedded Class 3B and 4 lasers shall be interlocked or fastened closed requiring special tools for removal.

4.1.1.3 When it is necessary to remove protective housings or service panels, a temporary laser controlled area shall be established. A temporary laser controlled area will not have the built-in protective features that are part of a laser-controlled area, but shall provide all safety requirements to protect personnel within and outside the area. Requirements for the temporary laser controlled area include, but are not limited to the following:

4.11.3.1 Restricted access to the area.

4.1.1.3.2 Control of the beam to prevent beam and reflections from extending beyond the restricted area.

4.1.1.3.3 Documented safe alignment techniques. (See Annex B.)

4.1.1.3.4 Removal of reflective materials in and near the beam path.

4.1.1.3.5 Appropriate laser eye protection if there is a possibility of exposure to laser radiation above the MPE. (See Annex C.)

4.1.1.3.6 A warning sign posted outside the area. (See Annex D.)

4.1.2 Collecting optics used to view the laser beam or its interaction with a material shall have permanently attached attenuators, filters or shutters to prevent hazardous levels of radiation from entering the eye. Laser hazard analyses shall be performed before using collecting optics to view Class 1, 2, and 3R laser beams to verify that the resulting eye exposure will be below the Class 3B MPE.

4.1.3 Laser Fiber Optic Cable Transmission Requirements

4.1.3.1 Laser transmission systems employing optical cables are considered to be enclosed systems with the optical cable forming part of the enclosure.

4.1.3.2 If disconnection of a connector results in accessible radiation that is below the applicable MPE due to the laser's Class or through the application of engineering controls, then connection or disconnection may take place in an uncontrolled area and no other control measures are required.

4.1.3.3 If disconnection of a connector could result in accessible radiation above the applicable MPE, the following precautions shall be taken:

4.1.3.3.1 Class 3B and Class 4 transmissions into the optical fiber or cable shall always be terminated before disconnecting a connector.

4.1.3.3.2 The connector shall bear a tag stating: "Hazardous Laser Radiation when Disconnected." In instances where multiple connectors are present in close proximity to each other, a single label, tag, or sign may be used as long as it's obvious which connectors the warning applies to.

4.1.3.3.3 During operation of lasers other than Class 3B or Class 4, connection or disconnection shall take place in an appropriate laser controlled area.

4.1.3.3.4 During maintenance, modification, or service activities, connection or disconnection shall take place in a temporary laser controlled area.

4.1.3.3.5 A tool shall be required to connect or disconnect connectors located outside of secured enclosures.

4.1.3.3.6 When connections or disconnections will take place within secured enclosures, no tool is required, but a warning sign appropriate to the class of laser or laser system shall be visible when the enclosure is open.

4.1.3.3.7 In instances where the optical fiber is greater than 10 feet in length, "protective housing labels" containing warnings that are appropriate for the laser's class (see Annex D) shall be placed at approximately 10-foot intervals along its length.

4.1.4 Ensure the beam height is not at the normal eye position of a person in a standing or seated position.

4.1.5 Position the laser so that the beam is not directed toward doorways or aisles.

4.1.6 If possible, securely mount the laser system to maintain the beam in a fixed position during operation and limit beam movements during adjustments.

4.1.7 Ensure beam path is well defined and controlled at all times.

4.1.8 Terminate the beam at the end of its useful path.

4.1.9 Use beam blocks and light curbs to the extent feasible to confine unwanted beams, reflections, and scatter to the optical table.

4.1.10 Install physical barriers to isolate the beam path and prevent accidental exposures when the beam must extend beyond the optical table.

4.1.11 Have only diffusely reflecting materials in or near the beam path, where feasible.

4.2 Additional Requirements for Class 3B and Class 4 Lasers and Laser Systems

4.2.1 The acquisition of a Class 3B or Class 4 lasers and lower class laser devices containing embedded Class 3B or 4 lasers shall be coordinated with the Laser Safety Officer. Coordination code RREQSA is set aside for review and approval of purchases via Work and Asset Management (WAM). Laser acquisition specifications should state that, as delivered, the laser, laser system, or laser product shall comply with the requirements of 21 CFR 1040, "Performance Standards for Light-Emitting Products."

NOTE: This may not apply to individual replacement components, or OEM components used by AEDC personnel to manufacture specialized lasers, laser systems, or laser products.

4.2.2 Before any class 3B and 4 laser or lower class laser device having embedded Class 3B or 4 laser, that is not a part of the AEDC inventory, is brought onto base for testing, evaluation, or demonstration purposes, the responsible test engineer, sponsor, or requestor shall coordinate with the LSO in advance of the planned date of use to ensure potential hazards are adequately assessed and appropriate countermeasures are identified and implemented. Lack of coordination or coordination less than 30 days before planned installation and operation of the device or system may result in termination of, or delays in, its use until all AEDC laser safety requirements are met.

4.2.3 Hazard analyses shall be developed for each Class 3B and Class 4 laser product and lower class laser products with embedded Class 3B or Class 4 lasers. The hazard analyses may apply to baseline laser system configurations, fixed laser system locations/installations, routine laser applications, or test-peculiar applications. The preferred approach is to develop a baseline hazard analysis for the laser or laser system to document its hazards, safety features, and applicable countermeasures; to address the basic mission phases such as setup, alignment, operation, and maintenance; and then to develop additional hazard analyses to address non-standard or test-peculiar applications that are not adequately covered by the baseline such as: the layout and establishment of temporary Laser Controlled Areas, area-specific lockout procedures, beam control implementation, the use of optics or fiber optics, and etc.

NOTE: A single hazard analysis may be used for multiple laser products when the following conditions are met:

- The lasers covered by the analysis have outputs, operating modes, beam parameters, applications, use locations, beam and non-beam hazards, and countermeasures that are identical, or
- The lasers covered by the hazard analysis are used interchangeably for the same application or in conjunction with one another; the hazards posed by the lasers/systems for the application are similar and the countermeasures address the worst credible hazards and effects posed by the individual lasers.

The hazard analysis shall include:

4.2.3.1 Laser output characteristics for the condition of use.

4.2.3.2 The Maximum Permissible Exposure (MPE) for the condition of use.

4.2.3.3 The boundary of the Nominal Hazard Zone and Laser Controlled Area. [Whenever possible, a sketch/drawing shall be attached to the System Safety Hazard Analysis (SSHA) showing the physical layout and applicable boundaries.]

4.2.3.4 Appropriate personal protective equipment required for safe use or operation.

4.2.3.5 Optical density required for laser safety eyewear.

4.2.3.6 Non-Beam hazards and subsequent control methods.

4.2.4 The results of the hazard analysis shall be documented on an SSHA for the operation, system, or test that involves the laser.

4.2.5 The hazard analysis and a completed Form GC-333 Laser Data shall be forwarded to the LSO for review, approval and inclusion in the base-wide inventory and database.

4.2.6 Written Work Instructions (WIs) are required for build-up, operating, alignment, maintenance and service activities. The WI shall be written by the RI and available to the LSO for review. WI shall be reviewed with all laser personnel and be posted in the area of the laser or laser system.

4.2.7 The manufacturer's operating manual is not a substitute for a WI.

4.2.8 Work Instructions should include the following:

4.2.8.1 Laser information

4.2.8.2 Contact information

4.2.8.3 Laser application

4.2.8.4 Control measures

4.2.8.5 Personal protective equipment

4.2.8.6 Startup and shutdown procedures

4.2.8.7 Experimental procedures

4.2.8.8 Emergency procedures

4.2.8.9 Storage instructions

4.2.8.10 Non-beam hazards (See Annex E.)

4.2.9 Nominal Hazard Zones (NHZ) shall be established for all Class 3B and Class 4 laser applications which require an open beam. The NHZ is the area in which the level of direct, reflected or scattered laser radiation exceeds the MPE. The LSO can assist in defining the NHZ.

4.2.10 Laser Controlled Areas shall be established for all Class 3B and Class 4 lasers. The laser controlled area will contain the NHZ. The walls, ceiling and floor of the room often define the laser controlled area.

4.2.11 Class 3B Laser Controlled Areas

4.2.11.1 Only personnel trained in the operation of the laser and laser safety shall be permitted to operate the laser or laser system

4.2.11.2 An individual knowledgeable in laser safety shall directly supervise the laser-controlled area.

4.2.11.3 The area shall be posted with the appropriate warning signs. (See Annex D.)

4.2.11.4 Restrict access to the laser controlled area.

4.2.11.5 Control the beam to prevent any misdirected beams or reflections.

4.2.11.6 Provide eye protection for all personnel working in the laser-controlled area.

4.2.11.7 Cover all windows and other openings to prevent laser radiation from extending beyond the laser-controlled area.

4.2.12 Class 4 Laser Controlled Areas

4.2.12.1 All of the requirements for a Class 3B laser-controlled area must be met. In addition, one of the following entryway controls must be incorporated into a Class 4 laser controlled area.

4.2.12.2 Non-Defeatable Entryway Safety Controls – Non-defeatable safety latches or interlocks that deactivate the laser or reduce the output to levels below the MPE in the event of unexpected entry are the preferred method of entryway control.

4.2.12.3 Defeatable Entryway Safety Controls – If non-defeatable controls limit the intended use of the laser, defeatable entryway safety controls may be used. Defeatable entryway controls allow authorized personnel to override the controls. Defeatable entryway controls may be used only if there is no laser radiation hazard at the point of entry. Personnel must be properly trained and provided with adequate personal protective equipment.

4.2.12.4 Procedural Entryway Controls – If safety latches or interlocks are not feasible, procedural entryway controls may be used. When procedural entryway controls are used, the following conditions must be met:

4.2.12.4.1 All authorized personnel shall be adequately trained.

4.2.12.4.2 Personal protective equipment shall be provided.

4.2.12.4.3 A door, barrier, screen or curtains shall be used to block or attenuate the laser radiation below the MPE at the entryway.

4.2.12.4.4 The entryway shall be equipped with a lighted laser warning sign that indicates the laser is operating.

4.2.13 Some lasers or laser systems have long warm-up times, and it may not be practical to turn the power off to the laser when the laser is not in use. In these cases, Class 3B lasers should be equipped with a permanently attached beam stop or attenuator and Class 4 lasers shall be equipped with a permanently attached beam stop or attenuator. The beam stop or attenuator must limit accessible laser radiation to below the MPE and be employed when the laser is not in use. For lasers that do not require warm-up time, the power to the laser shall be turned off when not in use.

4.2.14 The laser or laser system shall be operated at the lowest level of power or radiant energy required for the application.

4.3 Additional Control Measure for Class 3B and Class 4 Single Pulse or Intermittent Operations

An alarm, a warning light or a verbal "countdown" command shall be used during activation or startup of single pulse or intermittent operations.

4.4 Additional Control Measures for Class 3B and Class 4 Ultraviolet and Infrared Lasers

4.4.1 All of the control measures in Sections 4.1 and 4.2 must be met.

4.4.2 Visible or audible warning devices shall be installed in areas where accessible laser radiation may exceed the MPE. These warning devices shall be clearly identified and visible from all areas of potential exposure.

4.4.3 Gloves, face shield, and long sleeves shall be worn when manipulating UV beams if required by hazard analysis.

4.4.4 Shielding that will attenuate UV radiation levels to below the MPE shall be installed.

4.4.5 Infrared beam enclosures or backstops shall be constructed of infrared absorbent materials. Enclosures, backstops or other materials that may contact a Class 4 infrared laser shall also be fire resistant.

4.5 Medical Surveillance Requirements

4.5.1 Individuals operating Class 1, Class 2, and Class 3R lasers are exempt from medical surveillance, unless the results of a laser hazard analysis indicate that beams viewed with collecting optics exceed the Class 3R MPE.

4.5.2 Individuals operating Class 3B and Class 4 laser are required to have a baseline eye examination prior to using the laser. One purpose is to establish a baseline against which damage (primarily ocular) can be measured in the event of injury. A second purpose is to identify workers who might be at special risk from chronic exposure to selected continuous wave lasers. The medical exam consists of the following:

4.5.2.1 Ocular history – Past eye and family history are reviewed along with any current complaints concerning the eyes. Special emphasis is placed on systemic diseases which might produce ocular problems. Use of photosensitizing medications, such as phenothiazines and psoralens may lower the threshold for biological effects of the eyes and skin. Aphakic individuals would be subject to additional retinal exposure from blue and ultraviolet light. However, there should be no reason to deny employment to these individuals unless chronic viewing of these wavelengths is required.

4.5.2.2 Visual acuity – 20/20 (6/6 in each eye for far and near) with corrections (whether worn or not) is normal.

4.5.2.3 Amsler grid test – No distortion or missing portions of the grid pattern is normal.

4.5.2.4 Color vision – No color blindness is normal.

4.5.3 Any deviation from normal above or problems noted in the history require identification of the underlying pathology either by a funduscopic exam, or other tests as determined appropriate by the responsible medical or optometric examiner.

4.5.4 Baseline eye examinations are scheduled through the AEDC Dispensary.

4.5.5 An eye examination is required when an employee terminates work with lasers.

4.6 Operating Contractor Responsibilities

4.6.1 Installation Laser Safety Officer shall

4.6.1.1 Establish and maintain the AEDC laser safety standard.

4.6.1.2 Maintain the installation laser safety program.

4.6.1.3 Keep the Installation Commander and Operating Contractor Management apprised of health and safety issues involving lasers and effectiveness of measures to control non-ionizing radiation hazards.

4.6.1.4 Provide consultation on laser safety issues.

4.6.1.5 Conduct laser safety training for all personnel working with lasers.

4.6.1.6 Participate in safety audits and inspections of laser laboratories as required.

4.6.1.7 Provide assistance in evaluating and controlling hazards. This includes assisting RIs with pre-use surveys and/or hazard analyses on all new sources.

4.6.1.8 Maintain a base-wide inventory of all Class 3B and 4 lasers with information provided by RIs.

4.6.1.9 Participate in accident investigations involving lasers.

4.6.1.10 Coordinate medical surveillance with the Dispensary.

4.6.1.11 Review purchase requisitions of all new hazardous sources of non-ionizing radiation (i.e., 3B and 4 lasers).

4.6.2 Management of operations using lasers shall

4.6.2.1 When multiple lasers or laser systems are present, designate RIs for all Class 3B and Class 4 lasers and laser systems, and all Class 1 laser devices with embedded Class 3B and Class 4 lasers, to be responsible for overall operational safety of the laser, laser system, or laser area.

4.6.2.2 Ensure copies of the latest version of ANSI Z136.1 are available for their laser workers to reference.

4.6.2.3 Identify laser workers to Occupational Health so that appropriate medical surveillance can be conducted. This written notification should include the type and power of the laser(s) that may produce exposure. This requirement can be delegated to the RI.

4.6.2.4 Ensure personnel working with lasers receive eye exams when required, and schedule the eye exam with the dispensary before the personnel begin working with lasers for the first time.

4.6.2.5 Provide the necessary resources to ensure an effective laser safety program is maintained in all areas under their control.

4.6.3 Supervisors of personnel using lasers shall:

4.6.3.1 Ensure their employees receive required laser eye examinations before assigning them as laser workers.

4.6.3.2 Ensure their employees receive required laser safety training before assigning them as laser workers.

4.6.3.3 Immediately report any known or suspected hazardous laser radiation eye exposures to the LSO and Occupational Health.

4.6.4 Responsible Individuals shall:

4.6.4.1 Coordinate acquisition of laser devices with LSO prior to purchase. (See Paragraph 4.2.1.)

4.6.4.2 Ensure a hazard analysis has been completed and documented for each 3B and 4 laser. See Paragraphs 4.2.3 through 4.2.5.

4.6.4.3 Provide workers an opportunity to participate in the hazard analysis and development of controls.

4.6.4.4 Ensure **all** personnel working in the area under their control have received proper training in laser safety and other required training for the operation.

4.6.4.5 Ensure personnel working with lasers receive eye exams when required, and schedule the eye exam with the dispensary before the personnel begin working with lasers for the first time.

4.6.4.6 Ensure safe operation of lasers in their area of responsibility.

4.6.4.7 Ensure all personnel entering the area, including test customers and service contractors, understand the laser hazards and comply with all safety requirements.

4.6.4.8 Incorporate changes into procedures and re-evaluate hazard analysis as conditions change effecting safe operation.

4.6.4.9 Provide appropriate personal protective equipment for the operation at hand.

4.6.4.10 Ensure personnel immediately report vision problems or suspected exposures to supervision and Occupational Health.

4.6.5 Laser Workers shall:

4.6.5.1 Keep the RI assigned to their area fully informed of any departure from established procedures.

4.6.5.2 Make sure they are current in laser safety and related training.

4.6.5.3 Make sure they have received a laser eye exam prior to first work with lasers.

4.6.5.4 Obey all procedures; follow safe work practices outlined on the Job Safety Analysis (JSA).

4.6.5.5 Report any observed laser safety infractions, shortcomings, or failures to the LSO or RI in a timely manner.

4.6.5.6 Seek immediate medical attention if exposure to laser radiation is suspected.

4.6.6 Visitors/Incidental workers who must enter a laser controlled area shall:

4.6.6.1 Complete a laser safety briefing per Paragraph 5.4.

4.6.6.2 Obey all procedures and follow safe work practices outlined on the JSA.

4.6.6.3 Be aware of the Nominal Hazard Zone and never cross into it.

4.6.6.4 Confer with laser workers to find out where lasers are being used so that these areas can be avoided.

4.6.6.5 Report any observed laser safety infractions, shortcomings, or failures to the LSO or RI in a timely manner.

4.6.7 Operating Contractor Safety and Health Group shall:

4.6.7.1 Inspect laser operations and review procedures to ensure compliance with applicable safety requirements. (This should be accomplished in conjunction with existing surveys and inspections.)

4.6.7.2 Recommend controls, as appropriate, for safety hazards associated with laser operations (i.e., electrical and other non-radiation hazards.)

4.6.7.3 Manage the system safety hazard analysis process for lasers, coordinating appropriate technical review.

4.6.8 Operating Contractor (or designee) Occupation Health (dispensary) shall:

4.6.8.1 Schedule or provide medical examinations as required by ANSI Z136.1.

4.6.8.2 Conduct or arrange examinations in the event of an accidental exposure.

5.0 TRAINING REQUIREMENTS

5.1 RIs and Laser Workers involved with Class 3B and 4 lasers require initial and annual training.

5.1.1 Initial laser training topics shall include:

5.1.1.1 Fundamentals of laser operation

5.1.1.2 Bio-effects of laser radiation on the eye and skin

5.1.1.3 Significance of specular and diffuse reflections

5.1.1.4 Non-beam hazards of lasers

5.1.1.5 Laser and laser system classifications

5.1.1.6 Control measures

5.1.1.7 Overall responsibilities of management and employees

5.1.1.8 Other topics as determined by the LSO

5.1.2 Annual laser safety refresher training shall be conducted to maintain laser worker safety knowledge and awareness. Topics shall be determined by the LSO based on changes in laser safety program requirements, common observed work practices, common identified deficiencies, the occurrence of laser mishaps or close calls, and changes in available laser safety tools and equipment, or industry practices.

5.2 The LSO and others who are responsible for developing and implementing laser safety program requirements, evaluating laser hazards, and implementing laser hazard control measures; such as designated Responsible Individuals shall be provided with additional training as specified below. This training shall be repeated as necessary to maintain a level of proficiency that is commensurate with the complexity and severity of the lasers and hazards they work with. This training will satisfy the requirement for annual training during the year in which it is taken. Topics include the following:

5.2.1 Topics addressed in the initial training (Paragraphs 5.1.1 through 5.1.1.8)

5.2.2 Laser terminology

5.2.3 Types of lasers, wavelengths, pulse shapes, modes, power/energy

5.2.4 Basic radiometric units and measurement devices

5.2.5 MPEs

5.2.6 Laser hazard evaluations and other calculations

5.3 Annual laser safety awareness training shall be provided for all base employees. This training may be delivered as a toolbox topic, safety notice, base-wide news article, or other appropriate method. The topics addressed will be determined by the LSO and be appropriate for the laser hazards and issues that may affect the general base population. Topic examples include the following:

5.3.1 Simple explanation of a laser

5.3.2 Comparison between ordinary and laser light

5.3.3 Visible and invisible beams

5.3.4 Human aversion response and caution against intentional defeat

5.3.5 General explanation of laser classifications

5.3.6 Basic bio-effects for **t**he eyes and skin

5.3.7 Basic laser safety rules

5.4 Before being allowed to enter Class 3B or 4 Laser Controlled Areas, visitors and spectators shall be provided with a laser safety briefing containing enough information to ensure that no exposures occur. The briefing may be verbal and/or written (See Annex F for a written briefing example) as appropriate for the area. Briefing topics shall include:

5.4.1 A description of the laser hazard warning system

5.4.2 The types and degree of lasers hazards present

5.4.3 The required protective measures and procedures

6.0 INSPECTION/AUDITS

Not Applicable

7.0 REFERENCES

21 CFR Part 1040 Performance Standards for Light Emitting Products

AEDC Radiation Safety Handbook

AEDC SHE Standard B2 Lockout Tagout

AEDC SHE Standard B4 High Voltage Electrical Work

AEDC SHE Standard B6 Low Voltage Electrical Safety Related Work Practices

AEDC SHE Standard D4 Compressed Gas Cylinders

AEDC SHE Standard F2 Personal Protective Equipment

AEDC SHE Standard F4 Respiratory Protection

AFOSH Standard 48-139 Laser Radiation Protection Program

ANSI Z136.1 - Safe Use of Lasers

NFPA 115 - Standard for Laser Fire Protection

8.0 ANNEXES

A. Beam Enclosure

B. Laser Alignment Recommendations

C. Laser Safety Eyewear

D. Warning Signs and Labels

E. Non-Beam Hazards

F. Sample Written Visitor Laser Safety Briefing

9.0 SUPPLEMENT

NFAC A321-0801-XSP D12 – Lasers

Annex A
Beam Enclosure

A laser or laser system in which the entire beam path is enclosed and the enclosure fulfills all requirements of a protective housing is considered to be Class 1 and no further controls are needed. However, if the protective housing is removed, a temporary laser controlled area must be established and control measures applicable to the class of the embedded laser must be implemented. (See Sections 4.1 through 4.5 of this standard.)

Modifications to commercial laser systems must be evaluated by the LSO.

Requirements for protective housings:

1.0 Protective housings shall be provided on all laser products to prevent personnel exposure to laser and collateral radiation that exceeds the Class I Accessible Emission Limit at all times and in all locations that such access is not necessary for the product to perform its intended function.

2.0 Each portion of a protective housing which is designed to be removed or displaced during operation or maintenance, and which allows personnel access to laser or collateral radiation in excess of the Class I Accessible Emission Limit when displaced or removed, shall be provided with at least one safety interlock that prevents such access by reducing or terminating the laser emission.

3.0 The safety interlocks shall be designed to prevent access to laser radiation above the Class I AEL. (For example, the interlock may be electrically or mechanically interfaced to a shutter that interrupts the beam when the protective housing is opened or removed.)

4.0 The safety interlock shall be fail-safe. The use of redundant electrical series connected interlocks would fulfill this requirement.

5.0 Adjustments or procedures during service shall not cause the interlocks to be inoperative when the laser is placed back in operation.

6.0 The protective housing shall be labeled in accordance with ANSI Z136.1. (See Annex D)

7.0 The embedded laser shall be labeled in accordance with ANSI Z136.1. (See Annex D)

Annex B
General Alignment Considerations

More laser accidents occur during beam alignment than any other laser manipulation. The following techniques are recommended to prevent the potential for accidents:

1.0 Remove or cover all jewelry (watches, bracelets, necklaces, etc.) or other items (badges, badge holders, buttons, etc.) that may reflect the incident beam prior to alignment activities.

2.0 Evaluate the use of non-reflective tools if possible.

3.0 Exclude unnecessary personnel from the laser controlled area during alignment.

4.0 Perform alignment at the lowest possible power level.

5.0 Use low-power visible lasers for path simulation of high-power visible or invisible lasers, when possible.

6.0 Use a temporary beam attenuator over the beam aperture to reduce the level of laser radiation below the MPE, when possible.

7.0 Wear laser safety eyewear during alignment. Alignment eyewear may be used when aligning a low- power visible laser. (See Annex C)

8.0 Use beam display devices (image converter viewers or phosphor cards) to locate beams when aligning invisible lasers.

9.0 Use shutters or beam blocks to block high-power beams at their source except when needed during the alignment procedure.

10.0 Use beam blocks to block high-power beams downstream of the optics being aligned.

11.0 Use beam blocks or protective barriers when alignment beams could stray into areas with uninvolved personnel.

12.0 Place beam blocks behind optics such as turning mirrors to terminate beams that may miss the mirrors during alignment.

13.0 Locate and block all stray reflections before proceeding to the next optical component or section.

14.0 Ensure that all beams and reflections are terminated before resuming high-power operation.

Annex C
Laser Safety Eyewear

Enclosure of the laser equipment or the beam path is the preferred method of control. However, when enclosures are not feasible and there is a potential exposure to the beam or reflected beams at levels above the MPE, it may be necessary to wear protective eyewear.

1.0 Availability and Use of Laser Safety Eyewear

1.1 Laser safety eyewear shall be available and worn by laser operators, incident personnel and visitors in laboratories where a Class 3B or Class 4 laser is present and there is a potential exposure to the beam or reflected beams at levels above the MPE.

1.2 Laser safety eyewear is not required for Class 1, Class 1M, Class 2, Class 2M, Class 3a or Class 3R lasers unless intentional direct viewing is required. The need for using laser safety eyewear shall be determined based on a documented laser hazard assessment.

1.3 The RI is responsible for ensuring that appropriate eyewear is available and worn.

2.0 Selecting Laser Safety Eyewear

2.1 Laser safety eyewear is wavelength specific.

2.2 The following information is needed to select the appropriate laser safety eyewear:

2.2.1 Wavelength(s)

2.2.2 Mode of operation (continuous wave or pulsed)

2.2.3 Maximum exposure duration (assume worst case scenario)

2.2.4 Maximum irradiance (W/cm^2) or radiant exposure (J/cm^2)

2.2.5 Maximum permissible exposure (MPE)

2.2.6 Optical density (OD)

2.3 Contact the LSO, if necessary, for assistance in calculating the MPE/OD and selecting eyewear.

3.0 Eyewear Selection

Laser safety eyewear shall be chosen based on the level of protection needed to protect the eyes from a worst case scenario. If several laser safety eyewear products offer sufficient protection, the following factors should also be considered:

3.1 Visible light transmission

3.2 Effect on color vision

3.3 Field of view provided by the design of the eyewear

3.4 Reversible bleaching of absorbing media

3.5 Need for prescription lenses

3.6 Fit and comfort

3.7 Impact resistance

4.0 Types of Laser Safety Eyewear

4.1 Glass – Glass laser eyewear is heavier and more costly than plastic, but it provides better visible light transmittance. There are two types of glass lenses, those with absorptive glass filters and those with reflective coatings. Reflective coatings can create specular reflections and the coating can scratch, minimizing the protection level of the eyewear.

4.2 Polycarbonate – Polycarbonate laser eyewear is lighter, less expensive and offers higher impact resistance than glass, but allows less visible light transmittance.

4.3 Diffuse Viewing Only (DVO) – As the name implies, DVO eyewear is to be used when there is a potential for exposure to diffuse reflections only. DVO eyewear may not provide protection from the direct beam or specular reflections.

4.4 Alignment Eyewear – Alignment eyewear may be used when aligning low power visible laser beams. Alignment eyewear transmits enough of the specified wavelength to be seen for alignment purposes, but not enough to cause damage to the eyes. Alignment eyewear cannot be used during operation of high power or invisible beams and cannot be used with pulsed lasers.

5.0 Laser Safety Eyewear for Multiple Wavelengths

One pair of laser safety eyewear may not be sufficient when working with tunable or multiple wavelength lasers. Always check the OD and wavelength prior to use. Eyewear with multiband filters and flip-up eyewear are available for some applications.

6.0 Laser Safety Eyewear for Ultra-Fast (Femtosecond) Lasers

Temporary bleaching may occur from high peak irradiances from ultra-fast laser pulses. Contact the manufacturer of the laser safety eyewear for test data to determine if the eyewear will provide adequate protection before using them.

7.0 Labeling of Laser Safety Eyewear

Laser safety eyewear shall be labeled with the optical density and the wavelength(s) the eyewear provides protection for. Additional labeling may be added for quick identification of eyewear in multiple laser laboratories.

8.0 Inspection and Cleaning of Laser Safety Eyewear

8.1 Laser safety eyewear should be inspected periodically for the following:

8.2 Pitting, crazing, cracking and discoloration of the attenuation material.

8.3 Mechanical integrity of the frame.

8.4 Light leaks.

8.5 Coating damage.

9.0 Care of Laser Safety Eyewear

Follow manufacturers' instructions when cleaning laser safety eyewear. Use care when cleaning eyewear to avoid damage to absorbing filters or reflecting surface.

Annex D
Warning Signs, Labels, and Tags

1.0 Area Warning Signs

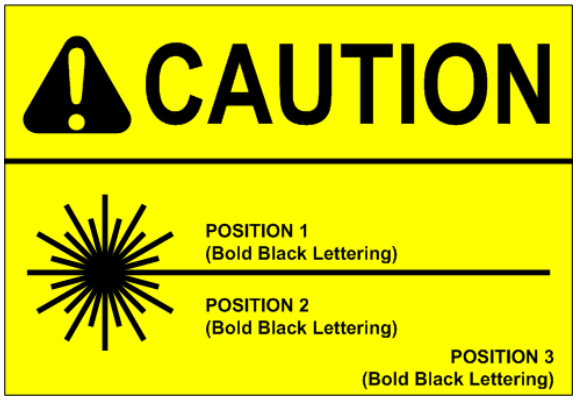
1.1 The purpose of a laser area warning signs is to communicate a rapid visual alerting message that:

- Warns personnel of area laser hazards
- Provides specific instructions regarding laser controls
- Communicates the severity of the hazard (e.g., class of laser, NHZ extent, etc.)
- Communicates appropriate action(s) to take to avoid the hazard (eyewear requirements, etc.)

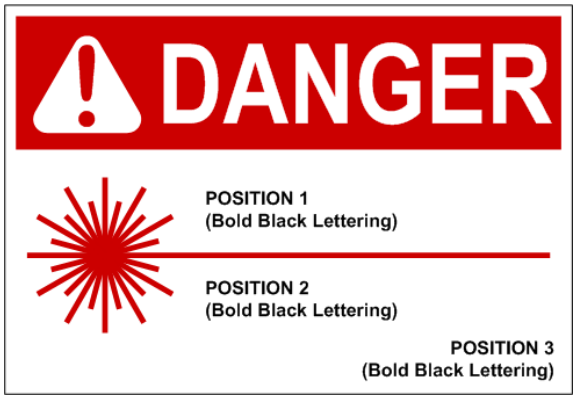
1.2 Warning sign contents may be modified with the LSO's approval to meet special needs/applications.

1.3 Warning signs shall be used to mark the boundaries of, and be visible without requiring entry into laser hazard areas; such as Laser Controlled Areas and Nominal Hazard Zones.

1.4 Warning signs are not normally required for areas where 2, and 2M lasers or laser systems are used. However, in instances where it is necessary to establish a Laser Controlled Area or post a warning sign on equipment where these devices are being used, signs shall conform to the "Caution" sign design specified by the most current version of ANSI Z136.1, as shown below.



All new warning signs being posted for Class 3R, Class 3B, and Class 4 Laser Controlled Areas shall conform to the "Danger" sign design specified by the most current revision of ANSI Standard Z136.1, as shown below.



Position 1 – Shall contain special precautionary instructions specific to the laser class, or protective action that may be applicable.

Precautionary Instruction Examples:

- Class 2 and lasers and laser systems, "Laser Radiation – Do Not Stare into Beam"

- Class 2M and 3R visible light (0.4 – 0.7 μm) lasers and laser systems with irradiance ≤ the MPE for a 0.25 second exposure – "Laser Radiation – Do Not Stare into Beam or View Directly with Optical Instruments."
- Class 3R lasers and laser systems (other than those specified above), "Laser Radiation – Avoid Direct Eye Exposure"
- Class 3B lasers and laser systems, "Laser Radiation – Avoid Direct Exposure to Beam"
- Class 4 lasers and laser systems, "Laser Radiation – Avoid Eye or Skin Exposure to Direct or Scattered Radiation"
  Note: The word "Radiation" on signs and labels may be replaced by the word "Light" for lasers operating in the visible range at wavelengths (0.4 - 0.7 μm). For lasers operating outside of this visible range the word "Invisible" shall be placed prior to the words "Laser Radiation."

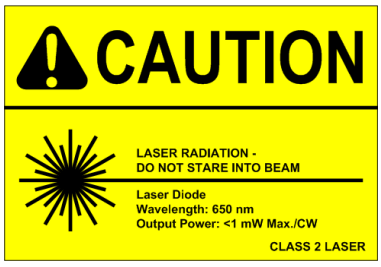
Protective Action Examples
- Laser Protective Eyewear Required
- Knock Before Entering
- Do Not Enter When Light is On
- Restricted Area

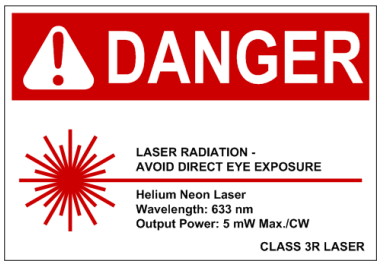
Position 2 – Shall contain information that's specific to the laser.
- Type of laser (Nd:YAG, Helium- Neon, etc.)
- Wavelength emitted
- Pulse duration (if appropriate)
- Maximum output

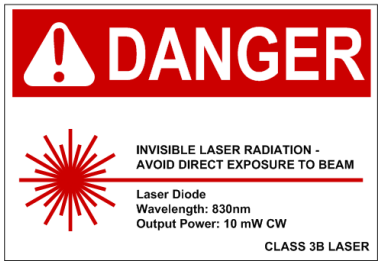
Position 3 – Shall contain the laser or laser system's Class.
- "Class 2 Laser"
- "Class 2M Laser"
- "Class 3R Laser"
- "Class 3B Laser"
- "Class 4 Laser"

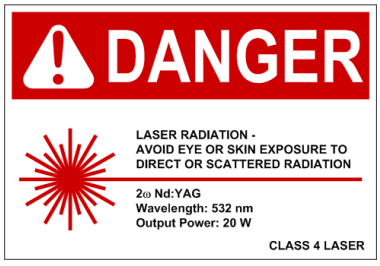
1.5 Existing warning signs that do not conform to the specifications; which may have an obsolete "Danger" logo for example, may remain in use as long as the information they contain does not conflict with that specified within paragraph 1.4. In instances where a conflict exists, the signs must be replaced.

1.6 Sample Area Warning Signs









2.0 Laser Product Labels and Tags

2.1 General

2.1.1 Federal law requires all lasers that are manufactured and/or sold in the United States to have warning labels or tags as specified in paragraphs 2.2 through 2.4.5 to certify compliance with the applicable requirements; identify the manufacturer; and identify the laser radiation hazards associated with them. Label and tag formats must comply with specifications contained in 21 CFR Part 1040 Performance Standards for Light-Emitting Products; or alternatively, may comply with the specifications contained within IEC 60825 Safety of Laser Products – Part 1: Equipment classification and requirements. Sample 21 CFR Part 1040 label formats; which are most common format encountered within the United States, are provided below. The label warning information (Positions 1 and 2) is as shown in 1.4. See Paragraph 2.4.1 for the 21 CFR Part 1040 "Caution" and "Danger" logos and Position 3 laser class descriptions.

2.1.2 Most labels described in this section (2.2 through 2.4.5) are applied by the laser's manufacturer to comply with federal law. Manufacturer's labels shall not be modified, defaced, or removed. The labels described by paragraphs 2.4.6 through 2.4.8 are specified by ANSI Z136.1. The minimum warning text specified by the ANSI standard must be included on these labels and tags; however, text may be added to improve their effectiveness.

2.1.3 Lasers whose labels are missing or have been defaced shall not be used until the required labels are replaced.

2.2 Certification Label

Each laser device shall have a permanently affixed or inscribed tag or label that is legible and readily visible when the product is fully assembled for use stating that the product conforms to all applicable standards under 21 CFR Part 1040.

2.3 Identification Label

Each laser device shall have a permanently affixed or inscribed tag or label that is legible and readily visible when the product is fully assembled for use stating the full name and address of the manufacturer of the product; or individual or company under whose name the product was sold; and the place, month, and year of manufacture.

2.4 Laser Hazard Labels and Tags

2.4.1 Protective Housing Label

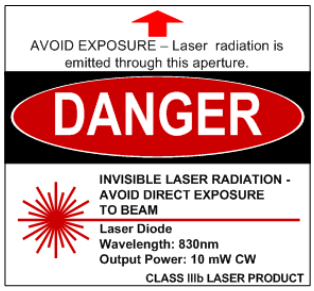
Each laser device's protective housing must have a permanently affixed or inscribed tag or label identifying its hazard class designation and the applicable laser hazard warning.

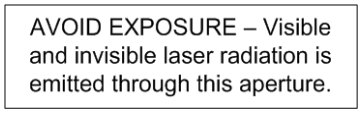
2.4.2 Control Panel Label

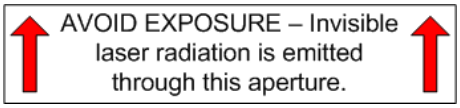
When the laser and control panel are separated by more than 6 feet, the labels or tags as shown in paragraph 2.4.1 shall be affixed to both the laser housing and control panel.

2.4.3 Aperture Label

A label stating: ‘‘AVOID EXPOSURE—Laser radiation is emitted from this aperture,’’ shall be affixed near each aperture through which laser or collateral radiation in excess of the Class I limits can be emitted. The label format is not specified; common examples are as follows:







Note: The label incorporating the “Danger” logo fulfills the requirements for both a housing and aperture label.

2.4.4 Non-Interlocked Protective Housing Label

Labels with the warning statements shown below shall be provided for each non-interlocked portion of the protective housing that is designed to be displaced or removed during operation, maintenance, or service; and could allow personnel access to laser or collateral radiation in excess of the Class I limits. The labels shall be:

- Visible on the protective housing before the portion of the protective housing is displaced or removed
- Placed in close proximity to the opening that will be created by removing or displacing the protective housing portion

Required wording is as follows:

- Class II – “CAUTION—Laser radiation when open. DO NOT STARE INTO BEAM.”
- Class IIIa, irradiance $\leq 2.5 \times 10^{-3}$ W/cm^2 – “CAUTION—Laser radiation when open. DO NOT STARE INTO BEAM OR VIEW DIRECTLY WITH OPTICAL INSTRUMENTS.”
- Class IIIa, irradiance $> 2.5 \times 10^{-3}$ W/cm^2 – “DANGER—Laser radiation when open. AVOID DIRECT EYE EXPOSURE.”
- Class IIIb – “DANGER—Laser radiation when open. AVOID DIRECT EXPOSURE TO BEAM.”
- Class IV – “DANGER—Laser radiation when open. AVOID EYE OR SKIN EXPOSURE TO DIRECT OR SCATTERED RADIATION.”

2.4.5 Defeatably-Interlocked Housing Label

Labels with the warning statements shown below shall be provided for each defeatably-interlocked portion of the protective housing that is designed to be displaced or removed during operation, maintenance, or service; and could allow personnel access to laser or collateral radiation in excess of the Class I limits. The labels shall be:

- Visible on the protective housing before the portion of the protective housing is displaced or removed
- Placed in close proximity to the opening that will be created by removing or displacing the protective housing portion

Required wording is as follows:

- Class II – “CAUTION—Laser radiation when open and interlock defeated. DO NOT STARE INTO BEAM.”
- Class IIIa, irradiance $\leq 2.5 \times 10^{-3}$ W/cm^2 – “CAUTION—Laser radiation when open and interlock defeated. DO NOT STARE INTO BEAM OR VIEW DIRECTLY WITH OPTICAL INSTRUMENTS.”
- Class IIIa, irradiance $> 2.5 \times 10^{-3}$ W/cm^2 – “DANGER—Laser radiation when open and interlock defeated. AVOID DIRECT EYE EXPOSURE.”
- Class IIIb – “DANGER—Laser radiation when open and interlock defeated. AVOID DIRECT EXPOSURE TO BEAM.”

- Class IV – "DANGER—Laser radiation when open and interlock defeated. AVOID EYE OR SKIN EXPOSURE TO DIRECT OR SCATTERED RADIATION."

2.4.6 Long Distance Beam Conduit and Long Distance Fiber Optic Cable Labels

Labels with the warning statements shown below shall be affixed to each beam conduit or fiber optic cable; other than fiber optic cables used for telecommunications, greater than 10 feet in length that contains laser radiation above the Class 1 limit. The labels shall be:

- Readily visible on the conduit's exterior
- Affixed at approximately 10-foot intervals along the conduit's length

The laser sunburst symbol may be used on these labels but isn't required. Applying labels meeting the requirements of paragraphs 1.3 or 2.4.1 would satisfy the labeling requirement, as would labels with the following warning statements:

- Class II – "CAUTION—Laser radiation. DO NOT STARE INTO BEAM."
- Class IIIa, irradiance $\leq 2.5x10^{-3}$ W/cm^2 – "CAUTION—Laser radiation. DO NOT STARE INTO BEAM OR VIEW DIRECTLY WITH OPTICAL INSTRUMENTS."
- Class IIIa, irradiance $> 2.5x10^{-3}$ W/cm^2 – "DANGER—Laser radiation. AVOID DIRECT EYE EXPOSURE."
- Class IIIb – "DANGER—Laser radiation. AVOID DIRECT EXPOSURE TO BEAM."
- Class IV – "DANGER—Laser radiation. AVOID EYE OR SKIN EXPOSURE TO DIRECT OR SCATTERED RADIATION."

2.4.7 Secured Fiber-Optic Cable Connector Enclosure Label

Labels/signs with warnings appropriate to associated laser or laser system's class shall be visible when a secured fiber-optic cable connector enclosure is open. Labels/signs meeting the requirements of paragraphs 2.4.1 or 2.4.6 will satisfy this requirement.

2.4.8 Unsecured Fiber-Optic Cable Connector Label

Labels or tags stating "Hazardous Laser Radiation when Disconnected" shall be applied to optical fibers or cables attached to Class 3B or Class 4 lasers or laser systems, if disconnection could expose personnel to laser radiation above the applicable exposure limit. In instances where multiple connectors are present in close proximity to each other, a single label, tag, or sign may be used as long as it's obvious that the warning applies to all fibers present.

Annex E
Non Beam Hazards

1.0 Electrical Hazards

The use of lasers or laser systems presents an electric shock hazard. Most lasers contain high-voltage power supplies and capacitors or capacitor banks that store lethal amounts of electrical energy. Exposures may occur from contact with energized components operating at potentials of 50 volts and above. These exposures most often occur during set up or installation, maintenance, modification and service when protective covers are removed. To reduce electrical hazards:

1.1 Lasers and associated electrical equipment must be designed, constructed, installed and maintained in accordance with the latest revision of the National Electric Code (NEC.)

1.2 When protective housings or covers will be removed, potentially exposing energized components, the following measures must be followed:

1.2.1 Adhere to the requirements of AEDC Safety Standards B2 Lockout Tagout, B4 High Voltage Electrical Work, and B6 Low Voltage Electrical Safety Related Work Practices.

1.2.2 Enclose high voltage sources and terminals whenever possible.

1.2.3 Turn off power and ground all high voltage points before working on power supplies.

1.2.4 Check that each capacitor is discharged and grounded prior to working near the capacitor. (Capacitors must be equipped with bleeder resistors, discharge devices or automatic shorting devices.)

1.2.5 Remove rings, watches or other jewelry when working with or near electrical equipment.

2.0 Laser-Generated Air Contaminants (LGAC)

Air contaminants may be generated when Class 4 and some Class 3B laser beams interact with matter. The quantity, composition and chemical complexity of the LGAC depend on the target material, cover gas and beam irradiance. Materials such as plastics, composites, metals and tissues may release carcinogenic, toxic and noxious air contaminants. Ozone is produced around flash lamps and can build up with high repetition rate lasers. Special optical materials used for far infrared windows and lenses may also release hazardous air contaminants. Concentrations of LGAC must be maintained below the exposure limits specified by OSHA, NIOSH or ACGIH. There are three major control measures to reduce the concentration of LGAC to acceptable levels as shown below. Contact the Operating Contractor Industrial Hygiene Office (IH) for assistance in assessing the LGAC and determining appropriate controls.

2.1 Use local exhaust ventilation to remove the LGAC at the point of generation. Local exhaust ventilation should be vented to the outside.

2.2 Isolate the process whenever possible.

2.3 Respiratory protection shall be used only when engineering controls are not feasible. Operating Contractor IH must be contacted prior to wearing a respirator. Refer to AEDC Safety Standard F4 for more information.

3.0 Collateral and Plasma Radiation

3.1 Collateral radiation (radiation not associated with the primary laser beam) may be produced by system components such as power supplies, discharge lamps and plasma tubes. Radiation may be in the form of X-rays, UV, visible, IR, microwave and radiofrequency (RF.)

3.2 When high power pulsed laser beams (peak irradiance of 10^{12} W/cm^2 or greater) are focused on a target, plasma is generated that may also emit collateral radiation.

3.3 Contact the LSO for evaluation of these hazards. The installation RSO will evaluate hazards associated with ionizing radiation.

4.0 Fire Hazards

4.1 Lasers classified as Class 3R, 3B and Class 4 may pose beam ignition hazards. Beam ignition hazards shall be assessed in accordance with NFPA 115 – Standard for Laser Fire Protection. In accordance with this standard, all Class 4 lasers shall be assumed to pose beam ignition hazards. Class 3R and 3B lasers that are

focused to produce an irradiance of 0.5 W/cm^2 or greater shall also be assumed to pose beam ignition hazards. To reduce the potential for beam ignition:

4.1.1 Terminate laser beams with non-combustible materials that are capable of withstanding the irradiance posed by the beam.

4.1.2 Bring only necessary materials into the laser area.

4.1.3 Store flammable and combustible gases, solvents, and materials properly and away from the laser beam.

4.1.4 Prevent hot or molten material that is ejected from the target, from coming into contact with flammable or combustible materials or gases.

4.2 Keep flammable liquids and gases away from laser electrical components that could serve as an ignition source.

4.3 Use appropriate local ventilation or other means to prevent oxidizing gases, which are used in conjunction with some lasers, from coming in contact with flammable or combustible liquids, solids, or gases.

5.0 Explosion Hazards

High-pressure arc lamps, filament lamps and capacitor banks may explode if they fail during operation. The laser target and elements of the optical train may shatter during operation. To reduce explosion hazards:

5.1 Enclose high-pressure arc lamps and filament lamps in housings that can withstand an explosion if the lamp disintegrates.

5.2 Enclose the laser target and optical train in protective housing during laser operation.

5.3 Ensure that capacitors are equipped with current-limiting devices and are shielded.

6.0 Compressed Gases

Hazardous gases are used in some laser applications including chlorine, fluorine, hydrogen chloride and hydrogen fluoride. Refer to AEDC Safety Standard D4 for more information on compressed gas safety. Laboratories with compressed gases are required to have an SOP.

7.0 Laser Dyes and Solvents

Laser dyes are complex fluorescent organic compounds that are dissolved in a solvent to form a lasing medium. Some dyes are highly toxic or carcinogenic. Most solvents suitable for dye solutions are flammable and toxic by inhalation and/or skin absorption. The following measures shall be followed when working with dyes:

7.1 Whenever possible, avoid using dimethylsulfoxide (DMSO) as a solvent for cyanine dyes because it aids in the transport of dyes through the skin and into the blood stream. If DMSO must be used, wear gloves. Disposable nitrile gloves may be worn if prolonged contact with DMSO is not anticipated. Other glove choices include neoprene and butyl gloves. PVA and PVC gloves are not recommended for use with DMSO. See AEDC Safety Standard F2 Personal Protective Equipment for more information.

7.2 Obtain material safety data sheets (MSDSs) for all dyes and solvents prior to working with them. MSDS resources are available via the AEDC Environmental web page.

7.3 Prepare and handle dye solutions in a fume hood.

7.4 Use disposable bench covers.

7.5 Wear a lab coat, safety glasses and gloves. Contact SHG for assistance with glove selection.

7.6 Pressure test all dye laser components before using dye solutions. Pay particular attention to tubing connections.

7.7 Install spill pans under pumps and reservoirs.

8.0 Noise

Noise levels from some lasers, such as pulsed excimer lasers, may be high enough to require hearing protection. Contact SHG for noise monitoring, labeling and assistance in selecting hearing protection.

Annex F
Sample Written Visitor Laser Safety Briefing

- Test and development activities are conducted in this facility using Class 3B and 4 visible and invisible lasers
- Direct exposure to the laser beam may result in skin burns and/or permanent or temporary vision loss or impairment
- Visitors and non-essential personnel may be prohibited from entering the building or be asked to leave when laser operations are pending or in progress
- When a laser hazard exists or may exist:
  - Laser hazard areas will be isolated by opaque barriers, closed curtains, and hazard warning tape
  - "Danger" signs that contain hazard warnings and identify the type and wavelength to the laser being operated will be posted
  - A red flashing beacon will be illuminated above the curtained entrance
- Unprotected and unauthorized personnel MAY NOT enter potential laser hazard areas during laser operation
- Those personnel who have a valid need to enter the laser hazard area during laser operation shall first:
  - Be briefed on the specific laser hazards and the associated countermeasures
  - Obtain and don required personal protective equipment
  - Obtain the laser operator's permission to enter

I have read and will comply with the requirements specified above

PRINTED NAME	ID #	EMPLOYER	SIGNATURE	DATE

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This supplement has been approved for the NFAC Site.

Review: This supplement will be reviewed and updated using the same cycle as the AEDC Standard D12 "Lasers."

References: AEDC Safety Standard D12 – Lasers at the AEDC NFAC Site.
NASA Ames Procedural Requirements APR 1700.1 Chapter 8 "Laser and Microwave Safety."

Scope:

This supplement establishes the laser safety requirements that are applicable at the NFAC. Laser light for purposes of this standard includes coherent electromagnetic emissions with wavelengths from 180 to 1,000,000 nanometers (nm); which includes the ultraviolet, visible, and infrared regions of the electromagnetic spectrum. This supplement applies to the possession and/or use of all lasers and laser systems used at NFAC.

This supplement applies to all NFAC personnel, customers and vendors.

NFAC Worksite Application:

NFAC shall follow the requirements specified in NASA Ames Procedural Requirements (APR) 1700.1 Chapter 8 "Laser and Microwave Safety".

NFAC shall obtain NASA Ames Non-ionizing Radiation Safety Committee (NRSC)[1] review, approval, and certification for the use of all Class 3B and Class 4 lasers within the facility. Once approved, the NRSC will issue a permit to operate the laser. See APG 1700.1 Chapter 8 for information on when the NRSC must review and approve the use of Class 3A[2] lasers for research and testing.

I. NFAC Site Management shall:

   Ensure that the requirements of APR 1700.1 Chapter 8 are fully implemented for laser operations and that this supplement is followed.

II. NFAC Supervisors and Test Directors shall:

   1. Ensure staff and customers follow the requirements specified within this supplement.
   2. Ensure that no Class 3B or Class 4 laser is activated until its use has been reviewed and approved by the Ames NRSC and NFAC Safety Engineer.
   3. Ensure that all engineered and administrative countermeasures, including the use of appropriate laser-protective eyewear, are implemented and enforced as specified in the required Laser Standard Operating Procedures.
   4. Ensure that only trained authorized laser users, laser workers, and junior authorized users, wearing the prescribed PPE are allowed to enter an established laser control area while the laser is capable of being energized.
   5. Ensure that all personnel have received the required laser safety training and baseline laser eye examination before assigning them to tasks where they could be exposed to Class 3B or Class 4 laser radiation.
   6. Ensure that appropriate lockout/tagout procedures are implemented to prevent unintended laser operation during periods when laser emissions are not required for alignment, calibration, servicing, or testing activities.

III. NFAC Safety Engineer/Management Designee shall:

   1. Assist in the Hazard Analysis with the System Safety Engineer on laser operations and establish SOPs with the Systems Safety Engineer and NRSC.

[1] The NASA Ames Laser Safety Officer participates in the NRSC review process.
[2] The NRSC does not review or approve the use of Class 3A laser pointing devices.

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2. Assess laser use to verify all engineered and administrative steps are implemented and enforced.
3. Coordinate with NRSC for final approval to use laser.
4. Coordinate with the Ames Health Unit and NFAC personnel to schedule baseline, post exposure, and termination laser eye examinations.
5. Ensure AEDC Operations Center notification of all actual or suspected Class 3B or Class 4 laser eye exposures.

IV. NFAC Staff shall:

1. Follow the requirements specified by this supplement.
2. Follow all administrative steps defined in the SOPs, to mitigate hazards identified in the Hazard Analysis.
3. Not override any engineering measures for laser safety.
4. Maintain laser safety training when lasers are installed at NFAC (annual requirement). If there are no lasers then on site current training is not required.
5. Obtain laser eye examinations as scheduled by the NFAC Safety Engineer.