LASER SAFETY

NIST S 7101.72
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1. PURPOSE

The purpose of this suborder is to establish requirements and associated roles and responsibilities for the use of lasers and laser systems (hereafter collectively referred to as "lasers") in laboratory/experimental and non-laboratory applications.

2. BACKGROUND

a. NIST P 7100.00 articulates NIST's commitment to making occupational safety and health an integral core value and vital part of the NIST culture by, in part, complying with applicable laws, regulations, and other promulgated safety and health requirements. Implementation of this suborder through the requirements in Section 6 and the roles and responsibilities in Section 9 meets those requirements.

b. This suborder supersedes NIST Health and Safety Instruction #13: *Laser Safety*.

c. Organizational Unit (OU) and/or division laser safety programs are supplemental to this program.

d. The content of this suborder is derived from the following:

(1) ANSI Z136.1-2014;

(2) ANSI Z136.8-2012; and

(3) ANSI Z136.6-2015 (when applicable).

[1] For revision history, see Appendix A.

3. APPLICABILITY

a. The provisions of this suborder apply to all NIST employees and covered associates[2] who engage in activities involving:

(1) Lasers for experimental purposes; and

(2) Laser pointers for demonstration, presentations, or other uses.

b. The provisions of this suborder do not apply to the use of lasers in surveying or construction applications at NIST.

4. REFERENCES

a. CFR Title 21 1040.10 and 1040.11 (2016) Performance Standards for Light-Emitting Products – Laser Products and Specific Purpose Laser Products.

b. American National Standards Institute (ANSI) Z136.1, 2014, American National Standard for the Safe Use of Lasers (or later revision).

c. American National Standards Institute (ANSI) Z136.6, 2015, American National Standard for the Safe Use of Lasers Outdoors (or later revision).

d. American National Standards Institute (ANSI) Z136.8, 2012, American National Standard for the Safe Use of Lasers in Research, Development or Testing (or later revision).

e. American National Standards Institute (ANSI) Z535.2 American National Standard for Environmental and Facility Safety Signs.

f. NFPA 70E: Standard for Electrical Safety in the Workplace (2015, or later revision). (available from OSHE).

g. NFPA 101: Life Safety Code (2015, or later revision). (available from OSHE)

h. NFPA 45: Standard on Fire Protection for Laboratories Using Chemicals (2015, or later revision). (available from OSHE).

i. Federal Aviation Administration Advisory Circular 70-1 Outdoor Laser Operations (2004).

[2] See NIST O 7101.00: Occupational Safety and Health Management System.

5. APPLICABLE NIST DIRECTIVES

a. NIST O 7101.00: *Occupational Safety and Health Management System*

b. NIST S 7101.20: *Work and Worker Authorization Based on Hazard Reviews*

c. NIST S 7101.21: *Personal Protective Equipment*

d. NIST S 7101.22: *Hazard Signage*

e. NIST S 7101.23: *Safety Education and Training*

f. NIST S 7101.53: *Magnetic Field Safety*

g. NIST S 7101.56: *Control of Hazardous Energy (Lock Out/Tag Out)*

h. NIST S 7101.59: *Chemical Hazard Communication*

i. NIST S 7101.60: *Chemical Management*

j. NIST S 7101.61: *Compressed Gas Safety*

k. NIST N 7104.64: *Electrical Safety*

l. NIST S 7101.68: *Incoherent Optical Radiation Safety*

m. NIST S 7101.70: *Radiofrequency and Microwave Radiation*

n. NIST S 7101.73: *Out of Service*

o. NIST P 7200.00: *Ionizing Radiation Safety*

p. NIST S 7201.03: *Ionizing Radiation Producing Machines at NIST-Gaithersburg*

q. NIST S 7201.04: *Ionizing Radiation Producing Machines at NIST-Boulder*

6. REQUIREMENTS

a. Lasers classifications shall be in accordance with the accessible emission limit for the respective laser classes.

(1) Manufacturer's classification shall only be valid if **no** modification to the laser has been made.

(2) Modified commercial lasers or custom manufactured lasers that are to be shipped to non-NIST customers and managed and operated by non-NIST personnel (which shall be interpreted here as introduction into commerce) shall have the classification reviewed by the NIST Laser Safety Officer (LSO) (non-delegable) prior to shipping, for compliance with 21 CFR 1040.10 and 1040.11.

(3) Lasers that are modified or custom manufactured for use in experimental processes and that are not intended to be introduced/re-introduced into commerce shall be re-evaluated through the hazard review process. This re-evaluation shall include classification to identify appropriate controls as required in this suborder, but are not subject to classification for compliance with 21 CFR 1040.10 and 1040.11.

b. Maximum permissible exposure (MPE) for eye and skin exposure shall be in accordance with those values found in ANSI Z136.1.

c. Authorization of Work

(1) Hazard Reviews to authorize work with lasers shall be:

(a) Required under specific conditions for each laser classification (Section 6.c(2));

i. Each subsequently higher classification shall include the applicable condition(s) identified in lower classifications; and

(b) Conducted in accordance with NIST S 7101.20: *Work and Worker Authorization Based on Hazard Reviews*.

i. The LSO (or delegate) shall be consulted as part of the Hazard Review process.

ii. When applicable, the LSO (or delegate) shall review and recommend approval of the following prior to work authorization by OU line management:

(i) Engineering controls;

(ii) Administrative controls, including, but not limited to:

[i] Standard operating procedures;

[ii] Beam alignment procedures; and

[iii] Hazard signage.

(iii) Personal protective equipment, including, but not limited to:

[i] Laser protective eyewear;

[ii] Laser alignment eyewear; and

[iii] Appropriate clothing to ensure adequate protection from cumulative low-level exposure to diffuse, or scattered UV radiation.

(2) Specific conditions requiring a Hazard Review for each laser classification (each laser class is defined in Section 7, **DEFINTIONS**). The Hazard Review may be conducted separately or as part of a larger activity review.

(a) Class 1 Lasers.

i. If the laser is **not** used for its original intent.

(b) Class 1M Lasers.

i. If optically aided observation with any form of light-collecting or magnifying optical instrument (*e.g.*, binoculars, telescope, microscope, loupe) is desired or possible; or

ii. If unattended operation will occur with the beam directed into a location where it can be directly viewed by unauthorized personnel and/or personnel that may be uninformed or unaware of the potential hazard.

(c) Class 2 Lasers.

i. If direct observation of the beam is desired.

(d) Class 2M Lasers.

i. If potentially hazardous optically aided observation of the beam is considered reasonably possible (intentional or unintentional).

(e) Class 3R Lasers (see Section 7, **DEFINITIONS**).

i. If direct viewing of the beam or specular reflection of the beam is desired;

ii. If the laser is operating at an invisible wavelength (<400 nm or >700 nm); or

iii. If operations occur in locations, whether indoors or outdoors (See Section 6d(6)(h)), where unauthorized personnel and/or personnel that may be uninformed or unaware of the potential hazard may be exposed to the beam.

(f) Class 3B Lasers (see Section 7, **DEFINITIONS**).

i. Under all operating conditions.

(g) Class 4 Lasers (see Section 7, **DEFINITIONS**).

i. Under all operating conditions.

(h) Simultaneous Laser Operation in a Workspace

i. Spaces where simultaneous operation of lasers will occur shall perform the following Hazard Reviews:

(i) If multiple lasers operate collectively as a system, regardless of their wavelength, then only one hazard review is required; and

(ii) If multiple lasers operate independently and have different configurations, then each laser/laser configuration should be taken into consideration during the hazard review process.

(3) Consideration of Additional Hazards

(a) Laser-related hazard reviews shall also address the following ancillary hazards, when appropriate:

i. Laser generated air contaminants (LGAC), when material is ablated, melted, or burned by laser radiation;

ii. Secondary radiation in the form of potential X-ray, UV, RF, microwave, and/or high magnetic fields;

iii. Electrical hazards when lasers operate at hazardous levels of voltage and current as determined through the hazard review process;

iv. Toxic hazards of the chemicals in gas, vapor, and dye lasers;

v. Use of compressed gases in lasers; and

vi. Use of lasers in the proximity of combustible or photo-reactive materials or chemicals.

d. Control Measures for Lasers
Where applicable, each subsequently higher classification shall include the control measure(s) identified in lower classifications.

(1) Class 1 Lasers (excluding embedded lasers, see Section 6d(6)(b))

(a) Engineering Controls

i. In general, engineering controls shall not be required for a Class 1 laser provided it is used for its original intent.

ii. If a Class 1 laser is **not** used for its original intent, a Hazard Review shall be required to determine if engineering controls are required.

(b) Administrative Controls

i. Class 1 lasers that are not commercially sourced, or have been modified, and have accessible laser radiation, shall have labels affixed to the laser with the following information:

(i) Class of the laser;

(ii) Emitted wavelength;

(iii) Pulse duration (if appropriate); and

(iv) Maximum power output.

ii. Purposeful direct viewing of a Class 1 laser beam shall only be conducted after the LSO (or delegate) determines the following:

(i) The laser's output complies with the classification given on the laser hazard label or in the manufacturer's operating manual; and

(ii) The laser is being used as the manufacturer intended.

(c) Personal Protective Equipment (PPE)

i. If a Class 1 laser is used for its original intent, PPE shall not be required.

ii. If a Class 1 laser is **not** used for its original intent, a Hazard Review shall be conducted to determine if PPE is required.

(2) Class 1M Lasers

(a) Engineering Controls

i. Engineering controls shall be determined by conducting a Hazard Review if the following conditions exist:

(i) Optically aided observation is expected or anticipated; or

(ii) Unattended operation will occur with the beam directed into a location where it can be directly viewed either by unauthorized personnel and/or personnel that may be uninformed or unaware of the potential hazard.

(b) Administrative Controls

i. Administrative controls shall be determined by conducting a Hazard review if the following conditions exist:

(i) Optically aided observation is expected or anticipated; or

(ii) Unattended operation will occur with the beam directed into a location where it can be directly viewed either by unauthorized personnel and/or personnel that may be uninformed or unaware of the potential hazard.

(c) PPE

i. In cases where aided observation is possible, a Hazard Review shall be conducted to determine what, if any, PPE is required.

(3) Class 2 and Class 2M Lasers

(a) Engineering Controls

i. Engineering controls, such as permanent filters or other attenuation or aperture-limiting methods, shall be determined by conducting a Hazard Review if direct observation of the beam is desired.

(b) Administrative Controls

i. Hazard signage, compliant with Section 6.f of this suborder, should be located at access points of the area of operation if there is the possibility of unauthorized personnel or unaware personnel encountering the direct beam from the laser.

ii. Direct observation of the beam should be avoided.

(i) In cases where direct viewing is desired (*e.g.*, use of direct optical aides such as loupes, telescopes, or binoculars) or cannot be avoided, a Hazard Review shall be required to ensure the risk is sufficiently mitigated.

(ii) Special provisions, such as filters, beam expansion, controls on the exposure time, may be developed to ensure that the beam's intensity is below the MPE for the viewing conditions.

(c) PPE

i. No additional PPE is required beyond that identified for Class 1M lasers unless aided observation is possible.

(i) In cases where aided observation is possible, a Hazard Review shall be conducted to determine what, if any, PPE is required.

(4) Class 3R Visible Lasers

(a) Engineering Controls

i. No additional engineering controls are required beyond those identified for Class 2M lasers.

(b) Administrative Controls

i. Class 3R visible lasers shall require the same administrative controls as a Class 2M laser.

(c) PPE

i. Laser eye protection shall not be required unless conditions exist where intentional long-term (> 0.25 s) direct viewing of the beam is intended or desired. If so, a Hazard Review shall be conducted and the laser shall be confirmed to meet the Class 3R limits for visible-only emissions and to determine what, if any, PPE is required.

(d) Handheld Class 3R visible lasers.

i. Handheld Class 3R visible lasers, typically referred to as “laser pointers”, shall be used in accordance with Section 6.g. of this suborder.

(5) Class 3R Invisible, Class 3B, and Class 4 Lasers
In addition to the requirements specified in this section, Class 3R invisible, Class 3B, and Class 4 lasers shall require the same engineering and administrative controls as a Class 3R visible laser.

(a) Engineering Controls

i. Controls shall be implemented to limit access to only those individuals authorized to work in that workspace when the hazard is present. Such controls may include, but are not limited to:

(i) Walls and doors to define the area of operation;

(ii) Locked doors to the area of operation with limitations on personnel that have access to the key or code to the door; and

(iii) Barriers, ropes, chains.

ii. Every entrance to the workspace, laboratory and/or Laser Control Area (LCA) shall, at minimum, have a mounted laser hazard indicator light with the following requirements:

(i) Shall be visible upon approach to the entrance(s);

(ii) Shall be mounted so as not to be flush with the mounting surface;

(iii) Shall be installed in such a manner so it is obvious which entrance the light is for (in cases where multiple laser hazard indicator lights are mounted in a single hallway or access way);

(iv) Shall be solid red in color;

(v) May flash or remain static when energized;

(vi) Shall operate only when the hazard is present, *i.e.*, the laser is energized and capable of emitting without disabling or bypassing of a control or interlock;

(vii) Where practical and reasonable, may be wired into the lasers;

[i] If the laser hazard indicator light is manually operated, such operation shall be clearly indicated in the appropriate hazard review documentation.

(viii) Shall be properly maintained to ensure functionality. If the laser hazard indicator is temporarily out of order:

[i] Clear and unambiguous signage indicating the current operating status of the laser shall be used in its place until repairs are made. Otherwise, the laser shall not be used.

iii. Entryway Safety Interlock Systems.

(i) Where practical and warranted by the hazards identified in the hazard review process, a safety interlock system should be implemented at every entrance to the space.

(ii) It is recommended that a safety interlock system be implemented if the laser will be operated in an unattended mode, *i.e.*, no individual authorized to be in that workspace is present in that workspace or at a remote operating site.

(iii) If a safety interlock system is implemented the following shall apply:

[i] The safety interlock system shall be designed to ensure potential exposures are below the MPE;

[ii] A visible indicator shall be used to indicate the safety status of the laser (*e.g.*, beam present or contained/off);

[iii] Without compromising the laser(s) in operation, the system shall be tested to ensure functionality at least annually;

[iv] The procedure for functionality testing shall be documented in the Hazard Review; and

[v] Records of functionality testing shall be maintained until the next functionality test has been documented.

(iv) If a safety interlock system is decommissioned, deactivated or shutdown, the laser access panel shall be:

[i] Removed; or

[ii] Tagged or locked out in accordance with the requirements of NIST S 7101.73: Out of Service.

iv. Laser Interlock

(i) Where practical, it is recommended that safety interlock systems, compliant with the requirements of Section 6d(5)(a)iii(iii) of this suborder, be implemented on laser enclosure panels.

(ii) Power supplies should have a method(s) to prevent unauthorized energization, *e.g.*, power switch key or master interlocks.

[i] Tags or locks shall be used in accordance with the requirements of NIST S 7101.73: *Out of Service*.

[ii] Locks associated with NIST S 7101.56: *Lock Out/Tag Out* shall not be used for this purpose.

v. Class 3R invisible, Class 3B, and Class 4 lasers shall be operated only in established LCAs, unless they are embedded and have no accessible laser emission(s).

(i) LCAs shall be designed, using walls, barriers, curtains, or other light blocking methods, to prevent laser radiation in excess of the MPE from exiting the area.

[i] For Class 4 lasers, potentially combustible materials shall not be used for construction of the LCA.

[ii] When the laser hazard is present, open portals to the LCA, *e.g.*, doorways, windows, breaks in walls/barriers/curtains, shall be covered or restricted to prevent laser radiation in excess of the MPE from exiting the LCA.

[iii] LCAs shall allow for the following in emergency situations:

- Admittance to the area by appropriate personnel; and
- Safe and rapid egress by operators.

[iv] A laser hazard indicator light, compliant with the requirements of Section 6d(5)(a)ii of this suborder, shall be mounted at each access point of a LCA.

(b) Administrative Controls

i. Unauthorized individuals shall be escorted at all times when the laser hazard is present by an individual authorized to work in that LCA.

ii. Hazard signage, compliant with the requirements of Section 6.f of this suborder, shall be posted at each access point of a LCA.

iii. Unless part of the experimental process that has been approved through the hazard review process, combustible materials shall be kept out of the laser beam path for Class 3B and 4 lasers.

iv. The following requirements should be implemented when designing the laser set-up (beam management and control):

(i) Enclose the laser beam to the maximum extent practical;

(ii) To the degree practical, keep the open laser beam path out of the normal line-of-sight (*e.g.*, standing height, work station height);

(iii) Mark or block access to areas where beams cross pedestrian or vehicular thoroughfares;

(iv) Position lasers so no laser beam or hazard exists at the room's entrance(s);

(v) Block unnecessary or unused laser beam reflections;

(vi) Terminate the beam(s) at the end of its useful path(s);

(vii) Confine all laser beams to a well-defined area of use; and

(viii) To the extent practical, remove specular (reflective) objects that may cause unexpected stray reflection (*e.g.*, jewelry, tools).

v. Hazard reviews shall be required for each Class 3R invisible, Class 3B, and Class 4 laser activity or operation. At a minimum, the laser related Hazard Review shall include the following information in the included hazard review documentation:

(i) Identify all laser hazards relevant to the Hazard Review, including:

[i] Wavelength;

[ii] Power/Energy;

[iii] Pulse duration (when applicable);

[iv] Repetition rate (when applicable); and

[v] Physical location.

(ii) Identify all controls applied as specified in this suborder

[i] Engineering; and

[ii] Administrative.

(iii) Identify laser specific PPE requirements, including:

[i] Wavelength coverage(s);

[ii] Optical Density (OD) requirement(s); and

[iii] Any relevant testing to confirm suitability of PPE beyond manufacturer specifications.

(iv) Identify actions needed in case of a suspected injury.

(v) Identify methods for securing the room in case of incident or emergency.

(vi) If multiple lasers operate:

[i] Collectively as a system, regardless of their class, then only one hazard review is required; or

[ii] Independently and have different configurations, then each laser/laser configuration should be taken into consideration during the hazard review process.

vi. Beam Alignment

(i) Beam alignment shall only be performed by users that are authorized to do so as established in the hazard review.

(ii) Beam alignment shall be conducted in a manner that minimizes, to the extent that is practical, the possibility of exposing personnel to the laser beam or to the beam's specular or diffuse reflection above the MPE.

(iii) Procedures shall be developed that do not require direct beam visualization. (*e.g.*, Phosphor card, IR viewer, Remote camera)

vii. When not in operation, lasers shall be:

(i) De-energized; and

(ii) Secured in a manner to prevent unauthorized energization.

(c) PPE

i. Laser Protective Eyewear

(i) The appropriate laser protective eyewear shall be identified as part of the Hazard Review process.

(ii) The LSO (or delegate) shall provide or confirm OD calculation(s) for laser protective eyewear as identified in the hazard review documentation.

(iii) Laser protective eyewear shall be conspicuously marked to indicate the OD and wavelength for which protection is afforded.

(iv) All personnel within the LCA shall wear laser protective eyewear appropriate to the hazards that are present at that time.

[i] If it is determined in the hazard review process that the likelihood of ocular exposure from direct or specularly reflected beams under normal circumstances is no more than

remote, then the eyewear requirement threshold for visible CW lasers may be raised to 25 mW.

(v) If multiple wavelengths are accessible simultaneously, laser protective eyewear that has sufficient OD for all accessible wavelengths shall be required.

(vi) If lasers are operating in the UV (<400 nm), full coverage goggles shall be used whenever practical to ensure protection from scattered and diffuse UV emissions.

(vii) Ultra-fast (< 1 ps pulse duration) lasers may have unanticipated spectral or non-linear effects on laser protective eye wear. As such, testing on candidate filter material should be conducted prior to their use as PPE. Guidance on testing shall be provided by the NIST LSO.

ii. Special Requirement for Laser Alignment Eyewear
In addition to the requirements for laser protective eyewear, laser alignment eyewear shall meet the requirements of this section.

(i) The LSO (or delegate) may allow, through the hazard review process, for reduced protection of eyewear when aligning visible lasers (400 nm to 700 nm) that shall not be less than 1.2 from the calculated values of OD required for exposure to the maximum power emitted by the laser in question.

(ii) Laser alignment eyewear shall be conspicuously marked to indicate they shall only be used for laser alignment.

(iii) Laser alignment eyewear shall be stored separately from laser protective eyewear.

(iv) Laser alignment eyewear shall be stored at all times unless actively in use.

iii. Clothing and Other PPE

(i) When operating UV lasers, appropriate clothing and PPE shall be selected to ensure adequate protection from cumulative low-level

exposure to diffuse, or scattered UV radiation hazards as identified in the hazard review process.

[i] Shall cover torso from neck to wrist;

[ii] Shall be made of a visibly opaque material (*e.g.*, lab coat); and

[iii] Gloves that are capable of attenuating UV exposure shall be considered if manual interaction with an active beam path is considered probable.

(ii) Polycarbonate face shields should be worn when long term interaction with diffuse UV light is considered a possibility.

iv. All PPE shall be inspected periodically to ensure it is not damaged or defective. Any damaged or defective PPE shall be taken out of service immediately.

(6) Special Conditions or Operations

(a) Simultaneous Laser Operation in a Workspace

i. Appropriate engineering and administrative controls identified above shall be required to address all accessible and hazardous wavelengths emitted during simultaneous operation of multiple lasers.

ii. Additional engineering and administrative controls shall be investigated to address potential hazards associated with the simultaneous operation of multiple lasers.

iii. A method to clearly communicate the relevant controls required based upon the simultaneous operation of multiple lasers shall be established as part of the Hazard Review process.

(b) Embedded Lasers

i. No further engineering controls are required to operate an embedded laser provided laser radiation is completely contained within the embedding apparatus during normal operation and shall be considered a Class 1 laser for the purposes of the Hazard Review and this suborder.

ii. Any removable portion of the embedding apparatus, *e.g.*, protective housing, service access panel, shall be labeled to indicate the hazard level of the enclosed laser(s).

iii. Any removable portion of the embedding apparatus, *e.g.*, protective housing, service access panel, that will allow access to laser radiation exposure in excess of the applicable MPE shall:

(i) Be interlocked; or

(ii) Require a special tool (or key) for opening or removal.

iv. When removing a portion of the embedding apparatus, *e.g.*, protective housing, service access panel, that will allow access to laser radiation in excess of the applicable MPE:

(i) A Hazard Review of that activity shall be required; and

(ii) A LCA shall be established that is compliant with the requirements for that classification of accessible laser radiation.

(c) High Energy Lasers (see Section 7, **DEFINITIONS**)

i. Engineering controls shall be implemented to the greatest extent practical for high energy lasers.

ii. Conventional laser PPE shall not be relied upon for protection from high energy lasers.

(i) If the calculated OD for laser protective eyewear is greater than or equal to OD 7, it is considered, for the purposes of this suborder, a high energy laser, and shall be taken into account during the hazard review process.

iii. Free-space operation of lasers where diffuse emission or reflection can exceed the MPE for the skin at a 10 cm working distance[3] shall be performed either:

[3] For example, this threshold can be 500 W under CW conditions at 1 µm wavelength. This is highly dependent on wavelength and pulse conditions (if any), and shall be evaluated by the LSO (or delegate) in the hazard review process.

(i) By fully enclosing the beam path to the extent of reducing exposure below the MPE (unless following the requirements of 6d(6)(b), all controls in this sub order for the relevant classification are still valid); or

(ii) Remotely, where the operator is physically removed from the LCA.

iv. All laser-matter interaction points shall be evaluated for potential LGAC and fire hazards.

v. For very high peak-power pulsed lasers where peak irradiances are equal to or greater than 10^{12} W/cm^2, all laser-matter interaction points, including all intermediate focal planes, shall be evaluated for potential ionizing radiation, and all appropriate controls are put in place in accordance with the relevant radiation safety program(s).

(d) Multi-Wavelength Lasers (see Section 7, **DEFINITIONS***)*

i. For lasers that simultaneously emit discrete wavelengths over multiple regions (UV, Visible, Near-IR, Mid-IR, *etc*.), it shall be ensured that all appropriate controls identified above (Engineering, Administrative, and PPE) are applied to all accessible wavelengths.

ii. If all emitted wavelengths are not needed/used simultaneously, the unneeded/unused wavelength beam paths should be enclosed or restricted to reduce the potential exposure to the hazard(s) those beams may represent.

(e) Broad-Spectrum Lasers (see Section 7, **DEFINITIONS**)

i. Broad-spectrum lasers that span across the visible spectrum shall be remotely viewed from:

(i) Within an enclosure; or

(ii) From outside the Nominal Hazard Zone (NHZ).

ii. During alignment operations, wavelength-selective filtering of the emission(s) should be performed.

(f) Fiber-Routed and Optical Fiber Lasers

i. Optical fibers that route laser emissions shall be considered an enclosed beam path with the optical fiber cable forming the enclosure along that path.

ii. The path of all fiber-routed lasers shall not contain any items or obstructions that may damage or break the fibers.

iii. Fiber optic cables for Class 4 lasers should have an armored or fireproof casing or jacket, whenever practical.

iv. Ends of Optical Fibers

(i) Optical fiber connectors shall be capped when not in use, whenever practical.

(ii) If the laser emission from the end of an optical fiber can result in exposure to laser radiation above the MPE, appropriate controls consistent with the hazard potential shall be applied.

(iii) Fiber end inspection should be performed with the fiber de-energized. If the inspection cannot be performed de-energized, the inspection method shall:

[i] Use indirect visualization methods (*e.g.*, TV camera); and

[ii] Never use direct optical methods (*e.g.*, eye loupe)

v. Flammable and/or combustible materials should be kept away from unarmored fibers transporting Class 4 laser radiation.

vi. Fiber optic cable that is routed outside of a Laser Control Area, and is transporting Class 3B or Class 4 laser radiation, shall be labeled with the appropriate hazard label (see Appendix B) at the following intervals:

(i) Where the cable is visible along the routed path (*e.g.*, cable tray), the cable shall be labeled at intervals no greater than 3 meters (m).

(ii) Where the cable routing is not visible along the entire path (*e.g.*, above a suspended tile ceiling), the labeling interval shall not be greater than 1 m.

(iii) Fiber optic cable that carries Class 3R or lower laser radiation beyond the LCA, should be labeled to appropriately identify that it is a fiber optic, but no mandatory interval is required.

(iv) Dedicated fireproof conduit shall be used where unarmored fiber optics carry Class 4 laser radiation beyond the perimeter of the laboratory or controlled area.

(g) Remote Operation

i. The operator shall visually inspect a remotely operated area before it is illuminated to ensure that:

(i) It is unoccupied; or

(ii) All occupants in the area are:

[i] Authorized Users;

[ii] In a safe location within the space; and

[iii] Wearing the proper PPE.

ii. Energizing of the laser(s) when the remote area may be occupied shall be preceded by:

(i) A visible warning, *e.g.*, Flashing light; and/or

(ii) An audible warning, *e.g.*, Beeper, or verbal call; and

(iii) A countdown to the status change.

(h) Outdoor Operation

i. With the exception of commercially available lasers that are specifically used in surveying, construction and similar activities, lasers shall be considered for hazard review in accordance with Section 6c(2) of this suborder.

ii. If the NHZ is accessible, laser safety observers shall be stationed to ensure unauthorized personnel are kept out of the NHZ.

iii. There shall be no unattended operation if the NHZ is accessible to unauthorized personnel.

iv. When lasers are operated above ground level, the hazard review must address the potential that a misdirected beam may propagate considerable distance and may contribute to visual interference even at exposures far below the MPE.

v. Whenever there is any potential for intersecting the flight path of an aircraft, advance notification to and approval from the Federal Aviation Administration is required. The NIST LSO shall provide guidance (non-delegable).

(i) Laser safety observers may be required as a condition of operating within navigable airspace to alert aircraft operators.

(ii) Calculation of both NHZ and visual interference threshold values (ANSI Z136.6 and AC 70-1) will be required.

vi. Night time operations shall require additional correction for increased sensitivity to intense light sources as a possible visual interference hazard.

e. Substitution of Alternate Control Measures

(1) If specified controls identified in preceding sections cannot be reasonably met, then upon review and recommendation for approval, on a case-by-case basis, by the LSO (non-delegable) as part of the hazard review process, the engineering and administrative controls specified above for Class 3R invisible, Class 3B and Class 4 lasers may be replaced by procedural, administrative or other alternative controls which provide equivalent protection. All personnel affected shall be provided appropriate training on the nature and implementation on such alternate control measures, and these control

measures shall be documented in the appropriate documentation included in the hazard review.

f. Laser Hazard Signage

(1) Laser hazard signage shall be posted in accordance with the requirements of this suborder.

(2) Laser hazard signage shall be compliant with NIST S 7101.22: *Hazard Signage*.

(3) Laser hazard signage shall display the following information:

(a) Minimum precautionary verbiage (See Appendix B, Table 1);

(b) Laser specific information;

i. Laser type

ii. Wavelength

iii. Maximum accessible power or energy

iv. Pulse conditions (when applicable)

(c) OD values the protective eyewear required for each laser listed on hazard sign. OD value shall be printed in red.

(4) Signal Words

(a) "Caution" may be used for Class 2 or Visible Class 3R lasers.

(b) "Warning" shall be used for invisible Class 3R, Class 3B and most Class 4 lasers.

a. Class 1M and Class 2M lasers where aided viewing is considered possible shall also use "Warning".

(c) "Danger" shall be used for Class 4 lasers where diffusely reflected or broadly scattered radiation can still be hazardous at range.

a. Examples can include but are not limited to:

i. UV lasers where scattered radiation from atmospheric transmission of the beam can expose personnel.

ii. High power lasers where scattered light from a beam dump or target is still hazardous at range.

iii. High peak power pulsed lasers where the generation of ionizing radiation is a potential hazard.

(d) "Notice" shall be used to indicate temporary change to the hazard condition.

i. "Notice" signs shall be used in conjunction with a laser hazard sign appropriate to the changed hazard.

(5) Fiber transport tags shall be used on Class 3B or Class 4 fibers that transition beyond the LCA as described in Section 6d(6)(f) of this suborder.

g. Handheld Devices Emitting Laser Radiation

(1) Handheld devices emitting laser radiation intended for use by NIST personnel or at NIST locations in demonstration or presentation settings, such as laser pointers, shall be tested by OSHE to determine if they meet the requirements of this suborder prior to first use after the effective date of this program[4].

(a) Handheld lasers that are tested in order to be used in demonstration or presentation settings shall be confirmed by OSHE to operate as Class 3R or less, visible wavelengths only.

(b) Devices that meet the requirements of this suborder shall be labeled as such and may be used by personnel with no further review or training.

(c) Devices that do not meet the requirements of this suborder, as it pertains to handheld lasers, shall be labeled as such. They are not to be used in demonstration or presentation settings without hazard review and shall only be used by appropriately trained personnel.

[4] Many laser pointers labeled and sold as Class 3R visible devices may in fact be emitting laser radiation at levels far greater than the 5 mW claim on the label. In addition, many such devices may also be emitting laser radiation at additional wavelengths besides the one indicated on the label.

(d) In the event staff encounter an unanticipated need to use a non-NIST-tested device, they shall ensure the requirements of Section 6.g(2) and 6.g(3) are followed.

(2) Handheld devices emitting laser radiation shall not be pointed at:

(a) Another individual; or

(b) A specular reflecting surface, *e.g.*, television screens, glass or shiny surfaces.

(3) Beams from handheld devices emitting laser radiation shall not be:

(a) Directly viewed; or

(b) Viewed with an optical instrument (such as binoculars or microscopes) unless such activity has been reviewed and approved through the Hazard Review process.

h. Medical Examination Following a Suspected or Actual Laser-Induced Injury

(1) Individuals who sustain an injury or suspect an injury from a laser exposure shall follow OU procedures for receiving medical examination and care.

(2) Under all circumstances, if an ocular (eye) exposure incident occurs, the affected individual(s) shall seek treatment from an **ophthalmologist** or **retinologist** as soon as practical.

i. Training

(1) Training shall be provided, documented, and recorded in accordance with the requirements of the NIST S 7101.23: *Safety Education and Training*.

(2) Individuals who work with invisible Class 3R, Class 3B, and Class 4 lasers shall receive the following training:

(a) On-Line training provided by OSHE for laser users that covers basic information to allow them to begin work in a supervised fashion; and

(b) Instructor-led training provided by OSHE on Laser Safety Awareness for Laser-Users to be taken when next available for the new laser-user; and

(c) Activity-specific on-the-job training required by applicable hazard reviews.

(3) Division Laser Safety Representatives (DLSRs) shall receive the following training to support their responsibilities:

(a) Laser Hazard Analysis Training to cover:

i. Interpretation of the ANSI Z136 Standards for exposure limit calculations;

ii. Calculation of Maximum Permissible Exposure; and

iii. Calculation of Optical Density values for laser protective eyewear.

(b) It is strongly recommended that DLSRs take Work and Worker Authorization Based on Hazard Review training to become familiar with application of controls to mitigate potential hazards.

(4) Individuals that may occasionally, in the course of their duties, be called to enter a laser lab unescorted but are not generally expected to use or work in the vicinity of lasers, shall receive OSHE provided Laser Safety Awareness training for non-users.

(a) Examples of such staff shall include, but may not be limited to:

i. First responders – Police, Fire, *etc*.

(5) The NIST LSO and DLSO shall receive documented Laser Safety Officer Training to support their responsibilities.

7. DEFINITIONS

a. Accessible (Beam) – If one can gain access to laser radiation in excess of the MPE without the elimination or bypassing of an approved control, then it shall be considered "accessible".

b. Accessible Emission Limit (AEL) **–** The maximum accessible emission level permitted within a particular laser class.

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

d. Administrative Control Measure – Control measures incorporating administrative means (*e.g*., training, safety approvals, LSO designation, and standard operating procedures) to mitigate the potential hazards associated with laser use.

e. Aperture – An opening, window, or lens through which optical radiation can pass. The aperture limits the energy or power for measurement or exposure.

f. Authorized Personnel – Individuals approved by management to operate, maintain, service, or install laser equipment.

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

h. Blink Reflex or Aversion Response – The closure of the eyelid or movement of the head to avoid exposure to a noxious stimulant of bright light. It generally occurs within 0.25 seconds.

i. Broad-Spectrum Laser – Any laser that is simultaneously emitting a continuum of radiation over an intentionally broad spectral range. For the purposes of this suborder, lasers emitting a continuous spectrum that spans greater than 200 nm shall be considered Broad-Spectrum. Such lasers may include, but are not limited to: Super-continuums, frequency combs, amplified spontaneous emission sources.

j. Collateral Radiation – Any electromagnetic radiation, except laser radiation, emitted by a laser. This does not include laser target interaction radiation (re-radiation).

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

l. Continuous Wave (CW) – The output of a laser, operated in a continuous rather than a pulsed mode. For purposes of safety evaluation, a laser that is operated with a continuous output for a period of 0.25 seconds or greater is typically regarded as a CW laser.

m. Control Measure – A means to mitigate potential hazards associated with the use of lasers. Within the hierarchy of controls, they are, in order of considered efficacy: Elimination, Substitution, Engineering Controls, Administrative Controls, and PPE. For the purposes of this suborder, it is already presumed that the hazard in question (Lasers) cannot be eliminated or substituted. The remaining control measures are: engineering, procedural (administrative), and personal protective equipment (PPE).

n. Diffuse Reflection – Change of spatial distribution of a beam of radiation when it is reflected in many directions by a surface or by a medium. Diffuse reflections are less hazardous than specular reflections for a given beam.

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

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

q. Enclosed Laser – A laser that is contained within a protective housing of itself or of the laser or system in which it is incorporated. Opening or removal of the protective housing provides additional access to laser radiation above the applicable MPE than possible with the protective housing in place.

r. Energy – The capacity for doing work. Energy content is commonly used to characterize the output from pulsed lasers and is generally expressed in Joules (J).

s. Engineering Controls – Methods of protecting others from exposure to laser radiation that requires no training on the behalf of those who may be exposed, e.g., interlocks and barriers.

t. High Energy Laser (HEL) – A high power CW laser, high energy pulsed laser, or high peak power pulsed laser.

u. Infrared Radiation – Electromagnetic radiation with wavelengths that lie within a range of 700 nm to 1 mm.

v. Irradiance (E) – Radiant power incident per unit area upon a surface, expressed in watts per square centimeter (W/cm^2).

w. LASER – A device that produces an intense, coherent, directional beam of light by stimulated emission of electronic or molecular transitions to lower energy levels. An acronym for "**L**ight **A**mplification by **S**timulated **E**mission of **R**adiation."

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

y. Laser Classification – An indication of the beam hazard level of a laser during normal operation, or the determination thereof. The hazard level of a laser is represented by a

number or a numbered capital letter. The laser classifications are Class 1, Class 1M, Class 2, Class 2M, Class 3R, Class 3B and Class 4.

(1) Class 1 Lasers – Any laser or laser product containing a laser that cannot emit laser radiation at levels that are known to cause eye or skin injury during normal operation. This does not apply to maintenance or service activities requiring access to Class 1 enclosures containing higher class lasers.

(2) Class 1M Lasers – A subcategory of Class 1 lasers is Class 1M. This classification describes laser products that are considered incapable of producing hazardous exposure unless viewed with collecting optics. These lasers are exempt from control measures unless optically aided viewing is possible.

(3) Class 2 Lasers – Laser products that emit solely in the visible portion of the spectrum (400 to 700 nm) at power levels of 1 mW or less. Eye protection is normally afforded by the natural aversion response, *i.e.*, the human eye will blink within an exposure time T less than 0.25 s when exposed to Class 2 laser light. These products are exempt from control requirements under normal operating conditions. As a matter of good practice, doors should be closed, and appropriate hazard signage may be posted.

(4) Class 2M Lasers – A subcategory of Class 2 lasers is Class 2M. This classification describes visible lasers that are safe to view by the unaided eye for 0.25 s. Like Class 1M, they are unsafe under some viewing conditions with optical aids. These lasers are exempt from control measures unless optically aided viewing is possible.

(5) Class 3 Lasers – Class 3 lasers may be hazardous under direct and specular reflection viewing conditions, but are normally not a diffuse reflection or fire hazard. The LSO (or delegate) can provide guidance or assistance for such classifications and appropriate control measures. Refer to Section 6d for control requirements. There are two subclasses within this classification:

(a) Class 3R lasers are potentially hazardous under some direct and specular reflection viewing conditions if the eye is appropriately focused and stable. Class 3R lasers have CW power levels no greater than 5 times the safe exposure limit. For visible lasers (400 nm to 700 nm), it is 5 times the Class 2 limit, or 5 mW. For invisible lasers (<400 nm or >700 nm), it becomes 5 times the Class 1 limit, which varies as a function of wavelength. Pulsed lasers have varying limits, dependent on wavelength, pulse duration, and repetition rate. Class 3R is roughly equivalent to earlier classification designations of "Class 3A", “3a” or “IIIa”. The most notable exception is for divergent-beam laser diodes and fiber-coupled lasers. Many such devices that

were previously classified as 3A may be Class 2M, or even Class 1M, in the new classifications.
For the purposes of this suborder, Class 3R lasers operating outside the visible spectrum (400 nm to 700 nm), shall be treated as Class 3B lasers, with the controls that are required for that classification.

(b) Class 3B lasers may be hazardous under direct and specular reflection viewing conditions. In general, they do not pose a significant skin hazard except for higher powered lasers operating at certain wavelength regions. Example: Class 3B visible lasers have power levels nominally greater than 5 mW and less than 0.5 W under CW operation. Under pulsed operation, ANSI Z136.1 must be consulted as the upper threshold is wavelength dependent.

(6) Class 4 Lasers – Class 4 lasers include all lasers that pose a hazard to the eye or skin from the direct or specular beam and may pose a diffuse reflection or fire hazard. Class 4 lasers may also produce LGAC and/or hazardous plasma radiation. These systems produce optical radiation at power and/or energy levels in excess of lasers designated as Class 3B or below.

z. Laser Generated Air Contaminants (LGAC) – Chemicals, compounds and/or particulate material that is generated as a result of laser-matter interactions such as, but not limited to: ablation, cutting, welding, *etc*.

aa. Laser Control Area (LCA) – An area within which there is the possibility of exposure to laser radiation in excess of the MPE. Perimeter boundaries are established to ensure there is no hazardous or excessive exposure outside of the LCA, and access is controlled to ensure only Authorized Users are permitted within the LCA when the laser hazard is present.

bb. Laser Pointer – Typically a handheld laser to be used in demonstrations, presentations, or other non-laboratory or non-experimental activities. These products shall be Class 1, Class 2, or Class 3R and only operate in the visible spectrum (400 nm to 700 nm).

cc. Laser Product – Any manufactured product or assemblage of components that constitutes, incorporates, or is intended to incorporate a laser. A laser intended for use as a component of an electronic product is itself considered a laser product.

dd. Laser Safety Officer (LSO) – One who has authority and responsibility to monitor and enforce the control of laser hazards and effect the knowledgeable evaluation and control of laser hazards.

ee. Laser System – An assembly of electrical, mechanical, and optical components that includes a laser.

ff. Maximum Permissible Exposure (MPE) – The level of laser radiation to which a person may be exposed without hazardous effect or adverse biological changes to 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.

gg. Multi-wavelength laser – Any laser that is capable of emitting multiple discrete wavelengths simultaneously.

hh. Nominal Hazard Zone (NHZ) – The workspace 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.

ii. Non-Beam Hazards (NBH) – All hazards arising from the presence of a laser, excluding direct human exposure to direct or scattered laser radiation.

jj. Optically Aided Viewing – Viewing with a telescopic (binocular) or magnifying optic. Under certain circumstances, viewing with an optical aid can increase the hazard from a laser beam.

kk. Optical Density (OD) – Logarithm to the base ten of the reciprocal of the transmittance: OD = $\log_{10}(1/T_\lambda)$, where T_λ is the transmittance at the wavelength of interest.

ll. Personal Protective Equipment (PPE) – Personal safety protective devices used to mitigate hazards associated with laser use (*e.g.*, laser eye protection, protective clothing, and gloves).

mm. Plasma Radiation – Laser target interaction radiation (LTIR) generated by a plasma.

nn. Power – The rate at which energy is emitted, transformed, or received in Watt or Joule/second. Also called the radiant power.

oo. Protective Housing – An enclosure that surrounds the laser and prevents access to laser radiation above the applicable MPE. The aperture through which the useful beam is emitted is not part of the protective housing. The protective housing limits access to other associated radiant energy emissions and to electrical hazards associated with components and terminals and may enclose associated optics and a workstation.

pp. Pulse Duration – The duration of a laser pulse, usually measured as the time interval between the half-power points on the leading and trailing edges of the pulse.

qq. Pulse-Repetition Frequency (PRF) – The number of pulses occurring per second, expressed in hertz.

rr. 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 less than 0.25 seconds.

ss. Radiant Exposure (H) – Surface density of the radiant energy received (J/cm^2).

tt. Radiant Flux (F) – Power emitted, transferred, or received in the form of radiation, expressed in Watts (also called radiant power).

uu. Specular Reflection – A mirror-like reflection typically resulting from a smooth, flat surface. Specular reflections are more hazardous than diffuse reflections for a given beam.

vv. Standard Operating Procedure (SOP) –A written step-by-step procedure or operational protocol used to document how a given task **must** be carried out to ensure safe operation. SOPs are generally needed when failure to follow a prescribed set of steps results in significant increase in risk.

ww. Transmittance – The ratio of total transmitted radiant power to the total incident radiant power.

xx. Ultraviolet Radiation (Light) – Electromagnetic radiation with wavelengths smaller than those of visible radiation; for the purpose of laser safety, 180 nm to 400 nm.

yy. 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 of 400 nm to 700 nm.

zz. Watt – The unit of power or radiant flux. 1 Watt = 1 Joule per second.

aaa. Wavelength – The distance between two successive points on a periodic wave that have the same phase.

8. ACRONYMS

a. AEL – Accessible Emission Limit

b. ANSI – American National Standards Institute

c. CSO – Chief Safety Officer

d. CW – Continuous Wave

e. DLSO – Deputy Laser Safety Officer

f. DLSR – Division Laser Safety Representative

g. DSR – Division Safety Representative

h. HEL – High Energy Laser

i. IR – Infrared

j. LCA – Laser Control Area

k. LGAC – Laser Generated Air Contaminants

l. LSAC – Laser Safety Advisory Committee

m. LSO – Laser Safety Officer

n. MPE – Maximum Permissible Exposure

o. NIST – National Institute of Standards and Technology

p. OD – Optical Density

q. OSHE – Office of Safety, Health, and Environment

r. OU – Operating Unit

s. PPE – Personal Protective Equipment

t. SOP – Standard Operating Procedure

u. UV – Ultraviolet

9. RESPONSIBILITIES

Roles and responsibilities common to all NIST OSH suborders can be found in Section 8 of NIST O 7101.00: *Occupational Safety and Health Management System*. The roles and responsibilities specific to this suborder are as follows:

a. OU Directors are responsible for:

(1) Establishing policies and procedures, as needed, for the requirements of this program to be met as it applies to their employees and covered associates and to lasers operated during their OU operations and ensuring that those policies and procedures are implemented; and

(2) Ensuring subordinate managers have the authority, resources, and training needed to implement OU-established policies and procedures.

b. CSO shall be responsible for designating NIST employees to serve as the LSO and DLSO.

c. Authorized Users are responsible for:

(1) Ensuring their own safety and the safety of those around them, including new users under observation;

(2) Operating lasers in accordance with this laser safety program at all times and ensuring that all requirements (Section 6) of this Suborder are met;

(3) Seeking guidance for situations not covered by this program, or that require clarification;

(4) Notifying safety representatives and supervisors of any unsafe situations or practices, as well as missing or inoperative laser safety equipment;

(5) Being vigilant for scope creep in terms of the boundaries established in the hazard review; and

(6) Notifying the DLSR of all new or altered laser installations.

d. Division Chiefs (or Equivalents)[5] are responsible for:

(1) Implementing this program as it applies to activities involving their personnel in accordance with any applicable OU-established policies and procedures;

(2) Allocating budgetary and other resources capable of ensuring the health and safety of employees, covered associates, and visitors in divisional work areas;

(3) Providing support to divisional group leaders, safety personnel, employees, and covered associates in carrying out their responsibilities with respect to implementing the requirements of this suborder and managing lasers within the division;

(4) Acting on all incidents involving lasers and related safety concerns reported by divisional personnel quickly and completely to protect employees and covered associates from the health and physical hazards presented by lasers in divisional work areas; and

(5) Designating the Division Laser Safety Representative(s) (DLSR). This designation acknowledges that the Division Chief has an appropriate degree of confidence, based on personal knowledge, observation, or reliable input from others, that the personnel to be designated as DLSR:

(a) Have the knowledge, skills, and abilities to evaluate the laser operations, evaluate hazards and determine safety controls; and

(b) Fully understand the boundaries/conditions imposed on the activity by the activity hazard review, the need to work within those boundaries/conditions, and the process for requesting work that falls outside of those boundaries/conditions.

e. Line Management is responsible for:

(1) Ensuring required training has been completed by affected employees and covered associates;

(2)

(3) Approving employees and associates as Authorized Users through the Hazard Review process to work in or around laser hazards in a laser control area; and

[5] Some NIST OUs do not have Division Chiefs; these OUs shall designate other individuals to carry out these responsibilities.

(4) Providing oversight as necessary aimed at ensuring that employees and covered associates who operate lasers do so in accordance with this suborder.

f. Division Laser Safety Representatives (DLSRs) are responsible for:

(1) Completing all training per the requirements of this suborder prior to engaging in DLSR responsibilities;

(2) As an element of the hazard review process, including new reviews, revisions, and renewals (not to exceed a three-year interval), determining whether their participation is warranted based on identified hazards and/or the extent of change(s) to the activity;

(a) If their participation is warranted or otherwise required by OU or Division policy, actively participating in hazard reviews.

(3) Conducting periodic review of any Division-level laser safety policy or supplemental programs.

(4) Bringing all potential laser safety issues to the attention of appropriate parties and informing the Division Chief of any unresolved issues;

(5) Serving as a delegate of the NIST LSO for the following responsibilities:

(a) Providing guidance, oversight, and administration necessary to help ensure Division compliance with this Suborder;

(b) Participating in the Hazard Review of new or altered laser installations;

i. Providing hazard analysis for laser-related reviews

(i) Establishing exposure limits

(ii) Establishing OD requirements for PPE

(iii) Recommending to management for Hazard Review approval based on controls applied in the Hazard Review process.

g. NIST Laser Safety Officer (LSO) is responsible for:

(1) Forming committees and establishing delegates as needed to successfully implement the laser safety program;

(2) Providing laser safety training opportunities, and providing assistance to the DLSRs;

(3) Participating in Division-level and OU-level laser hazard reviews and safety inspections upon request;

(4) Providing guidance on compliance with 21 CFR 1040 regarding introduction of lasers into commerce as needed;

(5) Providing guidance on testing of laser protective eyewear for conditions not met by manufacturers specifications; and

(6) Providing guidance on FAA and other agency communication and oversight as it pertains to outdoor laser operations.

h. NIST Deputy Laser Safety Officer (DLSO) is responsible for:

(1) Serving as a delegate of the NIST LSO for the following responsibilities:

(a) Assisting in the NIST level administration of this program;

(2) Assisting in providing laser safety training opportunities, and providing assistance to the DLSRs;

(3) Participating in Division-level and OU-level laser hazard reviews and safety inspections upon request.

10. AUTHORITIES

There are no authorities specific to this suborder alone.

11. DIRECTIVE OWNER

Chief Safety Officer

12. APPENDICES

A. Revision History

B. Signage

1497 **Appendix A. Revision History**

1498

Version No.	Approval Date	Effective Date	Brief Description of Change; Rationale
1	07/31/2019		• None – Initial document
2	05/09/2022	06/30/2023	• Section 5 – links were updated and the Out of Service safety program was added. • Sections 6.d(5)(a)iii(iv) and 6.d(5)(a)iv(ii) were updated to point to the Out of Service safety program. • Administrative updates - Footer updated to new page number format and version number, and updated Revision History table to use version number. • NOTE: Effective date was originally TBD due to the COVID-19 pandemic. It was updated on 4/17/23.
2a	01/23/25	01/23/25	Administrative Revision • Fixed two incorrect references to Section 6f - changed from 6e to 6f in lines 332 and 517.

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Appendix B: Examples of Laser Hazard Signs

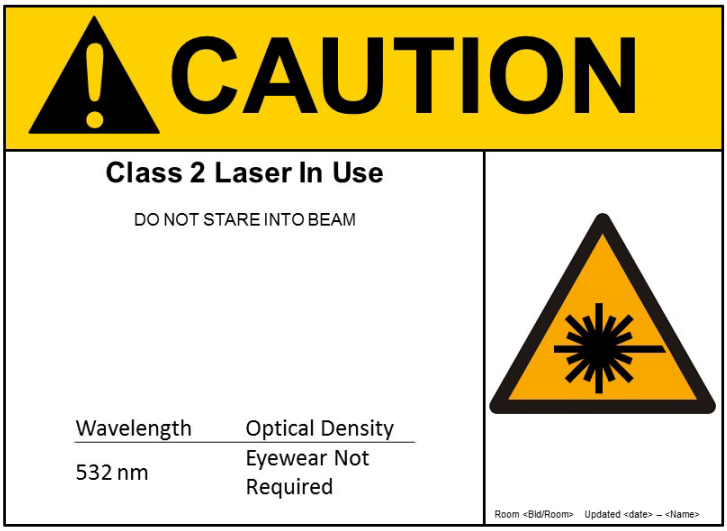
Laser hazard signs shall be posted outside of laboratories containing Class 3B, invisible 3R or Class 4 lasers or laser systems. Laser hazard signs are optional for laboratory containing visible Class 3R, and Class 2 lasers. Warning signs are not required for Class 1 lasers. The type, wavelength, and power (or pulse energy, duration, and repetition rate) of each laser shall be listed. The highest classification must be used to list all the lasers. For example, if a laboratory contains both Class 2 and 4 lasers, the Class 4 sign shall be used. Examples of the required signs are shown below (intended nominal size: 11" × 8.5"). Templates for common laser-warning signs are posted on the NIST safety website.

Table 1: Precautionary statements required to be on laser labels and hazard signs.

Laser Classification	Recommended Precautionary Statement
Class 1	None Required
Class 1M	LASER RADIATION – DO NOT VIEW DIRECTLY WITH OPTICAL INSTRUMENTS
Class 2	LASER RADIATION – DO NOT STARE INTO BEAM
Class 2M	LASER RADIATION – DO NOT STARE INTO THE BEAM OR VIEW DIRECTLY WITH OPTICAL INSTRUMENTS
Class 3R	LASER RADIATION – AVOID DIRECT EYE EXPOSURE
Class 3B	LASER RADIATION – AVOID EYE OR SKIN EXPOSURE TO DIRECT OR REFLECTED RADIATION
Class 4	LASER RADIATION – AVOID EYE OR SKIN EXPOSURE TO DIRECT, REFLECTED, OR SCATTERED RADIATION

Caution

The signal word "Caution" indicates a potentially hazardous situation which, if not avoided, may result in minor or moderate injury. The "Caution" sign shall optionally be used with all signs and labels associated with Class 1, Class 2 and visible Class 3R lasers and laser systems.



Warning

The signal word "Warning" indicates a hazardous situation which, if not avoided, may result in severe injury or death. The "Warning" sign shall be used with all signs and labels associated with invisible Class 3R, all Class 3B and all Class 4 lasers unless the hazard review identifies an extreme hazard. Examples of extreme hazards may include, but are not limited to: Lasers identified as HEL, scanning operations with lasers operating above Class 1M/2M, extended scattered or diffuse-light hazard.

Danger

The signal word "Danger" indicates a hazardous situation which, if not avoided, will result in severe injury or death. The "Danger" sign shall be used with all signs and labels associated with Class 4 lasers identified as HEL, scanning operations with lasers operating above Class 1M/2M, extended scattered or diffuse-light hazard, or other laser hazards as warranted and evaluated through the Hazard Review process.

Notice

When an area not normally posted as a laser control area contains temporarily accessible Class 3B (or invisible 3R) or Class 4 laser radiation (such as in the case of servicing of a device with an embedded laser), a sign, giving notice of the temporary hazard, shall be posted, as shown in the following example. The word "Notice" with a blue background is used for this sign. The "Notice" sign must accompany a laser hazard sign appropriate to the temporary hazard with specific details of the temporary hazard.

Fiber Optic Transport

Where Class 3B or Class 4 laser radiation is being transported by fiber in a shared or accessible cable tray outside of a laser control area, the following label is to be affixed to the fiber according to the requirements in Section 6.