

# LASER SAFETY

NIST S 7101.72

Document Approval Date: 07/31/2019

Effective Date:<sup>1</sup> 06/30/23

## 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).

---

<sup>1</sup> For revision history, see Appendix A.

34 **3. APPLICABILITY**

35 a. The provisions of this suborder apply to all NIST employees and covered associates<sup>2</sup> who  
36 engage in activities involving:

37

38 (1) Lasers for experimental purposes; and

39

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

41

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

44

45

46 **4. REFERENCES**

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

49

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

52

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

55

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

58

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

61

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

64

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

66

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

69

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

71

---

<sup>2</sup> See NIST O 7101.00: Occupational Safety and Health Management System.

72 **5. APPLICABLE NIST DIRECTIVES**

- 73 a. NIST O 7101.00: [Occupational Safety and Health Management System](#)  
74  
75 b. NIST S 7101.20: [Work and Worker Authorization Based on Hazard Reviews](#)  
76  
77 c. NIST S 7101.21: [Personal Protective Equipment](#)  
78  
79 d. NIST S 7101.22: *Hazard Signage*  
80  
81 e. NIST S 7101.23: [Safety Education and Training](#)  
82  
83 f. NIST S 7101.53: [Magnetic Field Safety](#)  
84  
85 g. NIST S 7101.56: [Control of Hazardous Energy \(Lock Out/Tag Out\)](#)  
86  
87 h. NIST S 7101.59: [Chemical Hazard Communication](#)  
88  
89 i. NIST S 7101.60: [Chemical Management](#)  
90  
91 j. NIST S 7101.61: [Compressed Gas Safety](#)  
92  
93 k. NIST N 7104.64: [Electrical Safety](#)  
94  
95 l. NIST S 7101.68: *Incoherent Optical Radiation Safety*  
96  
97 m. NIST S 7101.70: [Radiofrequency and Microwave Radiation](#)  
98  
99 n. NIST S 7101.73: [Out of Service](#)  
100  
101 o. NIST P 7200.00: [Ionizing Radiation Safety](#)  
102  
103 p. NIST S 7201.03: *Ionizing Radiation Producing Machines at NIST-Gaithersburg*  
104  
105 q. NIST S 7201.04: *Ionizing Radiation Producing Machines at NIST-Boulder*  
106  
107

108 **6. REQUIREMENTS**

- 109 a. Lasers classifications shall be in accordance with the accessible emission limit for the  
110 respective laser classes.  
111

- 112 (1) Manufacturer’s classification shall only be valid if **no** modification to the laser has been  
113 made.  
114
- 115 (2) Modified commercial lasers or custom manufactured lasers that are to be shipped to non-  
116 NIST customers and managed and operated by non-NIST personnel (which shall be  
117 interpreted here as introduction into commerce) shall have the classification reviewed by  
118 the NIST Laser Safety Officer (LSO) (non-delegable) prior to shipping, for compliance  
119 with 21 CFR 1040.10 and 1040.11.  
120
- 121 (3) Lasers that are modified or custom manufactured for use in experimental processes and  
122 that are not intended to be introduced/re-introduced into commerce shall be re-evaluated  
123 through the hazard review process. This re-evaluation shall include classification to  
124 identify appropriate controls as required in this suborder, but are not subject to  
125 classification for compliance with 21 CFR 1040.10 and 1040.11.  
126
- 127 b. Maximum permissible exposure (MPE) for eye and skin exposure shall be in accordance  
128 with those values found in ANSI Z136.1.  
129
- 130 c. Authorization of Work  
131
- 132 (1) Hazard Reviews to authorize work with lasers shall be:  
133
- 134 (a) Required under specific conditions for each laser classification (Section 6.c(2));  
135
- 136 i. Each subsequently higher classification shall include the applicable  
137 condition(s) identified in lower classifications; and  
138
- 139 (b) Conducted in accordance with NIST S 7101.20: *Work and Worker Authorization*  
140 *Based on Hazard Reviews.*  
141
- 142 i. The LSO (or delegate) shall be consulted as part of the Hazard Review  
143 process.  
144
- 145 ii. When applicable, the LSO (or delegate) shall review and recommend approval  
146 of the following prior to work authorization by OU line management:  
147
- 148 (i) Engineering controls;  
149
- 150 (ii) Administrative controls, including, but not limited to:  
151

- 152 [i] Standard operating procedures;
- 153
- 154 [ii] Beam alignment procedures; and
- 155
- 156 [iii] Hazard signage.
- 157
- 158 (iii) Personal protective equipment, including, but not limited to:
- 159
- 160 [i] Laser protective eyewear;
- 161
- 162 [ii] Laser alignment eyewear; and
- 163
- 164 [iii] Appropriate clothing to ensure adequate protection from
- 165 cumulative low-level exposure to diffuse, or scattered UV
- 166 radiation.
- 167

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

171

172 (a) Class 1 Lasers.

- 173
- 174 i. If the laser is **not** used for its original intent.
- 175

176 (b) Class 1M Lasers.

- 177
- 178 i. If optically aided observation with any form of light-collecting or magnifying
- 179 optical instrument (*e.g.*, binoculars, telescope, microscope, loupe) is desired or
- 180 possible; or
- 181
- 182 ii. If unattended operation will occur with the beam directed into a location
- 183 where it can be directly viewed by unauthorized personnel and/or personnel
- 184 that may be uninformed or unaware of the potential hazard.
- 185

186 (c) Class 2 Lasers.

- 187
- 188 i. If direct observation of the beam is desired.
- 189
- 190
- 191

- 192 (d) Class 2M Lasers.  
193  
194 i. If potentially hazardous optically aided observation of the beam is considered  
195 reasonably possible (intentional or unintentional).  
196
- 197 (e) Class 3R Lasers (see Section 7, **DEFINITIONS**).  
198  
199 i. If direct viewing of the beam or specular reflection of the beam is desired;  
200  
201 ii. If the laser is operating at an invisible wavelength (<400 nm or >700 nm); or  
202  
203 iii. If operations occur in locations, whether indoors or outdoors (See Section  
204 6d(6)(h)), where unauthorized personnel and/or personnel that may be  
205 uninformed or unaware of the potential hazard may be exposed to the beam.  
206
- 207 (f) Class 3B Lasers (see Section 7, **DEFINITIONS**).  
208  
209 i. Under all operating conditions.  
210
- 211 (g) Class 4 Lasers (see Section 7, **DEFINITIONS**).  
212  
213 i. Under all operating conditions.  
214
- 215 (h) Simultaneous Laser Operation in a Workspace  
216  
217 i. Spaces where simultaneous operation of lasers will occur shall perform the  
218 following Hazard Reviews:  
219  
220 (i) If multiple lasers operate collectively as a system, regardless of their  
221 wavelength, then only one hazard review is required; and  
222  
223 (ii) If multiple lasers operate independently and have different  
224 configurations, then each laser/laser configuration should be taken into  
225 consideration during the hazard review process.  
226
- 227 (3) Consideration of Additional Hazards  
228  
229 (a) Laser-related hazard reviews shall also address the following ancillary hazards, when  
230 appropriate:  
231

- 232 i. Laser generated air contaminants (LGAC), when material is ablated, melted,  
233 or burned by laser radiation;  
234
- 235 ii. Secondary radiation in the form of potential X-ray, UV, RF, microwave,  
236 and/or high magnetic fields;  
237
- 238 iii. Electrical hazards when lasers operate at hazardous levels of voltage and  
239 current as determined through the hazard review process;  
240
- 241 iv. Toxic hazards of the chemicals in gas, vapor, and dye lasers;  
242
- 243 v. Use of compressed gases in lasers; and  
244
- 245 vi. Use of lasers in the proximity of combustible or photo-reactive materials or  
246 chemicals.  
247

248 d. Control Measures for Lasers

249 Where applicable, each subsequently higher classification shall include the control  
250 measure(s) identified in lower classifications.  
251

252 (1) Class 1 Lasers (excluding embedded lasers, see Section 6d(6)(b))  
253

254 (a) Engineering Controls  
255

- 256 i. In general, engineering controls shall not be required for a Class 1 laser  
257 provided it is used for its original intent.  
258
- 259 ii. If a Class 1 laser is **not** used for its original intent, a Hazard Review shall be  
260 required to determine if engineering controls are required.  
261

262 (b) Administrative Controls  
263

- 264 i. Class 1 lasers that are not commercially sourced, or have been modified, and  
265 have accessible laser radiation, shall have labels affixed to the laser with the  
266 following information:  
267
  - 268 (i) Class of the laser;
  - 269
  - 270 (ii) Emitted wavelength;
  - 271

- 272 (iii) Pulse duration (if appropriate); and  
273  
274 (iv) Maximum power output.  
275  
276 ii. Purposeful direct viewing of a Class 1 laser beam shall only be conducted  
277 after the LSO (or delegate) determines the following:  
278  
279 (i) The laser's output complies with the classification given on the laser  
280 hazard label or in the manufacturer's operating manual; and  
281  
282 (ii) The laser is being used as the manufacturer intended.  
283  
284 (c) Personal Protective Equipment (PPE)  
285  
286 i. If a Class 1 laser is used for its original intent, PPE shall not be required.  
287  
288 ii. If a Class 1 laser is **not** used for its original intent, a Hazard Review shall be  
289 conducted to determine if PPE is required.  
290  
291 (2) Class 1M Lasers  
292  
293 (a) Engineering Controls  
294  
295 i. Engineering controls shall be determined by conducting a Hazard Review if  
296 the following conditions exist:  
297  
298 (i) Optically aided observation is expected or anticipated; or  
299  
300 (ii) Unattended operation will occur with the beam directed into a location  
301 where it can be directly viewed either by unauthorized personnel  
302 and/or personnel that may be uninformed or unaware of the potential  
303 hazard.  
304  
305 (b) Administrative Controls  
306  
307 i. Administrative controls shall be determined by conducting a Hazard review if  
308 the following conditions exist:  
309  
310 (i) Optically aided observation is expected or anticipated; or  
311



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

316  
317 (c) PPE

318  
319 i. In cases where aided observation is possible, a Hazard Review shall be  
320 conducted to determine what, if any, PPE is required.

321  
322 (3) Class 2 and Class 2M Lasers

323  
324 (a) Engineering Controls

325  
326 i. Engineering controls, such as permanent filters or other attenuation or  
327 aperture-limiting methods, shall be determined by conducting a Hazard  
328 Review if direct observation of the beam is desired.

329  
330 (b) Administrative Controls

331  
332 i. Hazard signage, compliant with Section 6.e of this suborder, should be located  
333 at access points of the area of operation if there is the possibility of  
334 unauthorized personnel or unaware personnel encountering the direct beam  
335 from the laser.

336  
337 ii. Direct observation of the beam should be avoided.

338  
339 (i) In cases where direct viewing is desired (*e.g.*, use of direct optical  
340 aides such as loupes, telescopes, or binoculars) or cannot be avoided, a  
341 Hazard Review shall be required to ensure the risk is sufficiently  
342 mitigated.

343  
344 (ii) Special provisions, such as filters, beam expansion, controls on the  
345 exposure time, may be developed to ensure that the beam's intensity is  
346 below the MPE for the viewing conditions.

347  
348 (c) PPE

349  
350 i. No additional PPE is required beyond that identified for Class 1M lasers  
351 unless aided observation is possible.

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

354

355 (4) Class 3R Visible Lasers

356

357 (a) Engineering Controls

358

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

361

362 (b) Administrative Controls

363

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

366

367 (c) PPE

368

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

374

375 (d) Handheld Class 3R visible lasers.

376

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

379

380 (5) Class 3R Invisible, Class 3B, and Class 4 Lasers

381 In addition to the requirements specified in this section, Class 3R invisible, Class 3B, and  
382 Class 4 lasers shall require the same engineering and administrative controls as a Class  
383 3R visible laser.

384

385 (a) Engineering Controls

386

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

390

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

- 392 (ii) Locked doors to the area of operation with limitations on personnel  
393 that have access to the key or code to the door; and  
394  
395 (iii) Barriers, ropes, chains.  
396  
397 ii. Every entrance to the workspace, laboratory and/or Laser Control Area (LCA)  
398 shall, at minimum, have a mounted laser hazard indicator light with the  
399 following requirements:  
400  
401 (i) Shall be visible upon approach to the entrance(s);  
402  
403 (ii) Shall be mounted so as not to be flush with the mounting surface;  
404  
405 (iii) Shall be installed in such a manner so it is obvious which entrance the  
406 light is for (in cases where multiple laser hazard indicator lights are  
407 mounted in a single hallway or access way);  
408  
409 (iv) Shall be solid red in color;  
410  
411 (v) May flash or remain static when energized;  
412  
413 (vi) Shall operate only when the hazard is present, *i.e.*, the laser is  
414 energized and capable of emitting without disabling or bypassing of a  
415 control or interlock;  
416  
417 (vii) Where practical and reasonable, may be wired into the lasers;  
418  
419 [i] If the laser hazard indicator light is manually operated, such  
420 operation shall be clearly indicated in the appropriate hazard  
421 review documentation.  
422  
423 (viii) Shall be properly maintained to ensure functionality. If the laser  
424 hazard indicator is temporarily out of order:  
425  
426 [i] Clear and unambiguous signage indicating the current  
427 operating status of the laser shall be used in its place until  
428 repairs are made. Otherwise, the laser shall not be used.  
429  
430  
431

- 432           iii.    Entryway Safety Interlock Systems.  
433  
434           (i)    Where practical and warranted by the hazards identified in the hazard  
435           review process, a safety interlock system should be implemented at  
436           every entrance to the space.  
437  
438           (ii)   It is recommended that a safety interlock system be implemented if the  
439           laser will be operated in an unattended mode, *i.e.*, no individual  
440           authorized to be in that workspace is present in that workspace or at a  
441           remote operating site.  
442  
443           (iii)   If a safety interlock system is implemented the following shall apply:  
444  
445                   [i]    The safety interlock system shall be designed to ensure  
446                   potential exposures are below the MPE;  
447  
448                   [ii]   A visible indicator shall be used to indicate the safety status of  
449                   the laser (*e.g.*, beam present or contained/off);  
450  
451                   [iii]   Without compromising the laser(s) in operation, the system  
452                   shall be tested to ensure functionality at least annually;  
453  
454                   [iv]   The procedure for functionality testing shall be documented in  
455                   the Hazard Review; and  
456  
457                   [v]    Records of functionality testing shall be maintained until the  
458                   next functionality test has been documented.  
459  
460           (iv)   If a safety interlock system is decommissioned, deactivated or  
461           shutdown, the laser access panel shall be:  
462  
463                   [i]    Removed; or  
464  
465                   [ii]   Tagged or locked out in accordance with the requirements of  
466                   NIST S 7101.73: Out of Service.  
467  
468  
469  
470  
471

- 472           iv.    Laser Interlock  
473  
474           (i)    Where practical, it is recommended that safety interlock systems,  
475           compliant with the requirements of Section 6d(5)(a)iii(iii) of this  
476           suborder, be implemented on laser enclosure panels.  
477  
478           (ii)   Power supplies should have a method(s) to prevent unauthorized  
479           energization, *e.g.*, power switch key or master interlocks.  
480  
481                [i]    Tags or locks shall be used in accordance with the  
482                requirements of NIST S 7101.73: *Out of Service*.  
483  
484                [ii]   Locks associated with NIST S 7101.56: *Lock Out/Tag Out*  
485                shall not be used for this purpose.  
486  
487    v.    Class 3R invisible, Class 3B, and Class 4 lasers shall be operated only in  
488    established LCAs, unless they are embedded and have no accessible laser  
489    emission(s).  
490  
491           (i)    LCAs shall be designed, using walls, barriers, curtains, or other light  
492           blocking methods, to prevent laser radiation in excess of the MPE  
493           from exiting the area.  
494  
495                [i]    For Class 4 lasers, potentially combustible materials shall not  
496                be used for construction of the LCA.  
497  
498                [ii]   When the laser hazard is present, open portals to the LCA, *e.g.*,  
499                doorways, windows, breaks in walls/barriers/curtains, shall be  
500                covered or restricted to prevent laser radiation in excess of the  
501                MPE from exiting the LCA.  
502  
503                [iii]   LCAs shall allow for the following in emergency situations:  
504  
505                    •    Admittance to the area by appropriate personnel; and  
506                    •    Safe and rapid egress by operators.  
507  
508                [iv]   A laser hazard indicator light, compliant with the requirements  
509                of Section 6d(5)(a)ii of this suborder, shall be mounted at each  
510                access point of a LCA.  
511

512 (b) Administrative Controls

513  
514  
515  
516  
517  
518  
519  
520  
521  
522  
523  
524  
525  
526  
527  
528  
529  
530  
531  
532  
533  
534  
535  
536  
537  
538  
539  
540  
541  
542  
543  
544  
545  
546  
547  
548  
549  
550  
551

- 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.e 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:

- 552 (i) Identify all laser hazards relevant to the Hazard Review, including:  
553  
554 [i] Wavelength;  
555  
556 [ii] Power/Energy;  
557  
558 [iii] Pulse duration (when applicable);  
559  
560 [iv] Repetition rate (when applicable); and  
561  
562 [v] Physical location.  
563  
564 (ii) Identify all controls applied as specified in this suborder  
565  
566 [i] Engineering; and  
567  
568 [ii] Administrative.  
569  
570 (iii) Identify laser specific PPE requirements, including:  
571  
572 [i] Wavelength coverage(s);  
573  
574 [ii] Optical Density (OD) requirement(s); and  
575  
576 [iii] Any relevant testing to confirm suitability of PPE beyond  
577 manufacturer specifications.  
578  
579 (iv) Identify actions needed in case of a suspected injury.  
580  
581 (v) Identify methods for securing the room in case of incident or  
582 emergency.  
583  
584 (vi) If multiple lasers operate:  
585  
586 [i] Collectively as a system, regardless of their class, then only  
587 one hazard review is required; or  
588  
589 [ii] Independently and have different configurations, then each  
590 laser/laser configuration should be taken into consideration  
591 during the hazard review process.

- 592 vi. Beam Alignment  
593  
594 (i) Beam alignment shall only be performed by users that are authorized  
595 to do so as established in the hazard review.  
596  
597 (ii) Beam alignment shall be conducted in a manner that minimizes, to the  
598 extent that is practical, the possibility of exposing personnel to the  
599 laser beam or to the beam's specular or diffuse reflection above the  
600 MPE.  
601  
602 (iii) Procedures shall be developed that do not require direct beam  
603 visualization. (e.g., Phosphor card, IR viewer, Remote camera)  
604  
605 vii. When not in operation, lasers shall be:  
606  
607 (i) De-energized; and  
608  
609 (ii) Secured in a manner to prevent unauthorized energization.  
610  
611 (c) PPE  
612  
613 i. Laser Protective Eyewear  
614  
615 (i) The appropriate laser protective eyewear shall be identified as part of  
616 the Hazard Review process.  
617  
618 (ii) The LSO (or delegate) shall provide or confirm OD calculation(s) for  
619 laser protective eyewear as identified in the hazard review  
620 documentation.  
621  
622 (iii) Laser protective eyewear shall be conspicuously marked to indicate  
623 the OD and wavelength for which protection is afforded.  
624  
625 (iv) All personnel within the LCA shall wear laser protective eyewear  
626 appropriate to the hazards that are present at that time.  
627  
628 [i] If it is determined in the hazard review process that the  
629 likelihood of ocular exposure from direct or specularly  
630 reflected beams under normal circumstances is no more than



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

633  
634 (v) If multiple wavelengths are accessible simultaneously, laser protective  
635 eyewear that has sufficient OD for all accessible wavelengths shall be  
636 required.

637  
638 (vi) If lasers are operating in the UV (<400 nm), full coverage goggles  
639 shall be used whenever practical to ensure protection from scattered  
640 and diffuse UV emissions.

641  
642 (vii) Ultra-fast (< 1 ps pulse duration) lasers may have unanticipated  
643 spectral or non-linear effects on laser protective eye wear. As such,  
644 testing on candidate filter material should be conducted prior to their  
645 use as PPE. Guidance on testing shall be provided by the NIST LSO.

646  
647 ii. Special Requirement for Laser Alignment Eyewear  
648 In addition to the requirements for laser protective eyewear, laser alignment  
649 eyewear shall meet the requirements of this section.

650  
651 (i) The LSO (or delegate) may allow, through the hazard review process,  
652 for reduced protection of eyewear when aligning visible lasers (400  
653 nm to 700 nm) that shall not be less than 1.2 from the calculated  
654 values of OD required for exposure to the maximum power emitted by  
655 the laser in question.

656  
657 (ii) Laser alignment eyewear shall be conspicuously marked to indicate  
658 they shall only be used for laser alignment.

659  
660 (iii) Laser alignment eyewear shall be stored separately from laser  
661 protective eyewear.

662  
663 (iv) Laser alignment eyewear shall be stored at all times unless actively in  
664 use.

665  
666 iii. Clothing and Other PPE

667  
668 (i) When operating UV lasers, appropriate clothing and PPE shall be  
669 selected to ensure adequate protection from cumulative low-level

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

- 672
- 673 [i] Shall cover torso from neck to wrist;
  - 674
  - 675 [ii] Shall be made of a visibly opaque material (*e.g.*, lab coat); and
  - 676
  - 677 [iii] Gloves that are capable of attenuating UV exposure shall be
  - 678 considered if manual interaction with an active beam path is
  - 679 considered probable.

680

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

683

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

687

## 688 (6) Special Conditions or Operations

689

### 690 (a) Simultaneous Laser Operation in a Workspace

- 691
- 692 i. Appropriate engineering and administrative controls identified above shall be
  - 693 required to address all accessible and hazardous wavelengths emitted during
  - 694 simultaneous operation of multiple lasers.
  - 695
  - 696 ii. Additional engineering and administrative controls shall be investigated to
  - 697 address potential hazards associated with the simultaneous operation of
  - 698 multiple lasers.
  - 699
  - 700 iii. A method to clearly communicate the relevant controls required based upon
  - 701 the simultaneous operation of multiple lasers shall be established as part of the
  - 702 Hazard Review process.

703

### 704 (b) Embedded Lasers

- 705
- 706 i. No further engineering controls are required to operate an embedded laser
  - 707 provided laser radiation is completely contained within the embedding
  - 708 apparatus during normal operation and shall be considered a Class 1 laser for
  - 709 the purposes of the Hazard Review and this suborder.

- 710           ii. Any removable portion of the embedding apparatus, *e.g.*, protective housing,  
711           service access panel, shall be labeled to indicate the hazard level of the  
712           enclosed laser(s).  
713
- 714           iii. Any removable portion of the embedding apparatus, *e.g.*, protective housing,  
715           service access panel, that will allow access to laser radiation exposure in  
716           excess of the applicable MPE shall:  
717
- 718                   (i) Be interlocked; or  
719
- 720                   (ii) Require a special tool (or key) for opening or removal.  
721
- 722           iv. When removing a portion of the embedding apparatus, *e.g.*, protective  
723           housing, service access panel, that will allow access to laser radiation in  
724           excess of the applicable MPE:  
725
- 726                   (i) A Hazard Review of that activity shall be required; and  
727
- 728                   (ii) A LCA shall be established that is compliant with the requirements for  
729                   that classification of accessible laser radiation.  
730
- 731           (c) High Energy Lasers (see Section 7, **DEFINITIONS**)  
732
- 733           i. Engineering controls shall be implemented to the greatest extent practical for  
734           high energy lasers.  
735
- 736           ii. Conventional laser PPE shall not be relied upon for protection from high  
737           energy lasers.  
738
- 739                   (i) If the calculated OD for laser protective eyewear is greater than or  
740                   equal to OD 7, it is considered, for the purposes of this suborder, a  
741                   high energy laser, and shall be taken into account during the hazard  
742                   review process.  
743
- 744           iii. Free-space operation of lasers where diffuse emission or reflection can exceed  
745           the MPE for the skin at a 10 cm working distance<sup>3</sup> shall be performed either:  
746

---

<sup>3</sup> For example, this threshold can be 500 W under CW conditions at 1  $\mu\text{m}$  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.

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

751  
752 (ii) Remotely, where the operator is physically removed from the LCA.

753  
754 iv. All laser-matter interaction points shall be evaluated for potential LGAC and  
755 fire hazards.

756  
757 v. For very high peak-power pulsed lasers where peak irradiances are equal to or  
758 greater than  $10^{12}$  W/cm<sup>2</sup>, all laser-matter interaction points, including all  
759 intermediate focal planes, shall be evaluated for potential ionizing radiation,  
760 and all appropriate controls are put in place in accordance with the relevant  
761 radiation safety program(s).

762  
763 (d) Multi-Wavelength Lasers (see Section 7, **DEFINITIONS**)

764  
765 i. For lasers that simultaneously emit discrete wavelengths over multiple regions  
766 (UV, Visible, Near-IR, Mid-IR, *etc.*), it shall be ensured that all appropriate  
767 controls identified above (Engineering, Administrative, and PPE) are applied  
768 to all accessible wavelengths.

769  
770 ii. If all emitted wavelengths are not needed/used simultaneously, the  
771 unneeded/unused wavelength beam paths should be enclosed or restricted to  
772 reduce the potential exposure to the hazard(s) those beams may represent.

773  
774 (e) Broad-Spectrum Lasers (see Section 7, **DEFINITIONS**)

775  
776 i. Broad-spectrum lasers that span across the visible spectrum shall be remotely  
777 viewed from:

778  
779 (i) Within an enclosure; or

780  
781 (ii) From outside the Nominal Hazard Zone (NHZ).

782  
783 ii. During alignment operations, wavelength-selective filtering of the emission(s)  
784 should be performed.

785  
786

- 787 (f) Fiber-Routed and Optical Fiber Lasers  
788  
789 i. Optical fibers that route laser emissions shall be considered an enclosed beam  
790 path with the optical fiber cable forming the enclosure along that path.  
791  
792 ii. The path of all fiber-routed lasers shall not contain any items or obstructions  
793 that may damage or break the fibers.  
794  
795 iii. Fiber optic cables for Class 4 lasers should have an armored or fireproof  
796 casing or jacket, whenever practical.  
797  
798 iv. Ends of Optical Fibers  
799  
800 (i) Optical fiber connectors shall be capped when not in use, whenever  
801 practical.  
802  
803 (ii) If the laser emission from the end of an optical fiber can result in  
804 exposure to laser radiation above the MPE, appropriate controls  
805 consistent with the hazard potential shall be applied.  
806  
807 (iii) Fiber end inspection should be performed with the fiber de-energized.  
808 If the inspection cannot be performed de-energized, the inspection  
809 method shall:  
810  
811 [i] Use indirect visualization methods (*e.g.*, TV camera); and  
812  
813 [ii] Never use direct optical methods (*e.g.*, eye loupe)  
814  
815 v. Flammable and/or combustible materials should be kept away from  
816 unarmored fibers transporting Class 4 laser radiation.  
817  
818 vi. Fiber optic cable that is routed outside of a Laser Control Area, and is  
819 transporting Class 3B or Class 4 laser radiation, shall be labeled with the  
820 appropriate hazard label (see Appendix B) at the following intervals:  
821  
822 (i) Where the cable is visible along the routed path (*e.g.*, cable tray), the  
823 cable shall be labeled at intervals no greater than 3 meters (m).  
824

- 825 (ii) Where the cable routing is not visible along the entire path (*e.g.*, above
- 826 a suspended tile ceiling), the labeling interval shall not be greater than
- 827 1 m.
- 828
- 829 (iii) Fiber optic cable that carries Class 3R or lower laser radiation beyond
- 830 the LCA, should be labeled to appropriately identify that it is a fiber
- 831 optic, but no mandatory interval is required.
- 832
- 833 (iv) Dedicated fireproof conduit shall be used where unarmored fiber
- 834 optics carry Class 4 laser radiation beyond the perimeter of the
- 835 laboratory or controlled area.
- 836

837 (g) Remote Operation

- 838
- 839 i. The operator shall visually inspect a remotely operated area before it is
- 840 illuminated to ensure that:
- 841
- 842 (i) It is unoccupied; or
- 843
- 844 (ii) All occupants in the area are:
- 845
- 846 [i] Authorized Users;
- 847
- 848 [ii] In a safe location within the space; and
- 849
- 850 [iii] Wearing the proper PPE.
- 851
- 852 ii. Energizing of the laser(s) when the remote area may be occupied shall be
- 853 preceded by:
- 854
- 855 (i) A visible warning, *e.g.*, Flashing light; and/or
- 856
- 857 (ii) An audible warning, *e.g.*, Beeper, or verbal call; and
- 858
- 859 (iii) A countdown to the status change.
- 860
- 861
- 862
- 863
- 864

865 (h) Outdoor Operation

- 866
- 867 i. With the exception of commercially available lasers that are specifically used
- 868 in surveying, construction and similar activities, lasers shall be considered for
- 869 hazard review in accordance with Section 6c(2) of this suborder.
- 870
- 871 ii. If the NHZ is accessible, laser safety observers shall be stationed to ensure
- 872 unauthorized personnel are kept out of the NHZ.
- 873
- 874 iii. There shall be no unattended operation if the NHZ is accessible to
- 875 unauthorized personnel.
- 876
- 877 iv. When lasers are operated above ground level, the hazard review must address
- 878 the potential that a misdirected beam may propagate considerable distance and
- 879 may contribute to visual interference even at exposures far below the MPE.
- 880
- 881 v. Whenever there is any potential for intersecting the flight path of an aircraft,
- 882 advance notification to and approval from the Federal Aviation
- 883 Administration is required. The NIST LSO shall provide guidance (non-
- 884 delegable).
- 885
- 886 (i) Laser safety observers may be required as a condition of operating
- 887 within navigable airspace to alert aircraft operators.
- 888
- 889 (ii) Calculation of both NHZ and visual interference threshold values
- 890 (ANSI Z136.6 and AC 70-1) will be required.
- 891
- 892 vi. Night time operations shall require additional correction for increased
- 893 sensitivity to intense light sources as a possible visual interference hazard.
- 894

895 e. Substitution of Alternate Control Measures

- 896
- 897 (1) If specified controls identified in preceding sections cannot be reasonably met, then upon
- 898 review and recommendation for approval, on a case-by-case basis, by the LSO (non-
- 899 delegable) as part of the hazard review process, the engineering and administrative
- 900 controls specified above for Class 3R invisible, Class 3B and Class 4 lasers may be
- 901 replaced by procedural, administrative or other alternative controls which provide
- 902 equivalent protection. All personnel affected shall be provided appropriate training on the
- 903 nature and implementation on such alternate control measures, and these control

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

906

907 f. Laser Hazard Signage

908

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

911

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

913

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

915

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

917

918 (b) Laser specific information;

919

920 i. Laser type

921

922 ii. Wavelength

923

924 iii. Maximum accessible power or energy

925

926 iv. Pulse conditions (when applicable)

927

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

930

931 (4) Signal Words

932

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

934

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

936

937 a. Class 1M and Class 2M lasers where aided viewing is considered possible  
938 shall also use “Warning”.

939

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

942

943



- 944 a. Examples can include but are not limited to:
- 945
- 946 i. UV lasers where scattered radiation from atmospheric transmission of
- 947 the beam can expose personnel.
- 948
- 949 ii. High power lasers where scattered light from a beam dump or target is
- 950 still hazardous at range.
- 951
- 952 iii. High peak power pulsed lasers where the generation of ionizing
- 953 radiation is a potential hazard.
- 954
- 955 (d) “Notice” shall be used to indicate temporary change to the hazard condition.
- 956
- 957 i. “Notice” signs shall be used in conjunction with a laser hazard sign
- 958 appropriate to the changed hazard.
- 959
- 960 (5) Fiber transport tags shall be used on Class 3B or Class 4 fibers that transition beyond the
- 961 LCA as described in Section 6d(6)(f) of this suborder.
- 962
- 963 g. Handheld Devices Emitting Laser Radiation
- 964
- 965 (1) Handheld devices emitting laser radiation intended for use by NIST personnel or at NIST
- 966 locations in demonstration or presentation settings, such as laser pointers, shall be tested
- 967 by OSHE to determine if they meet the requirements of this suborder prior to first use
- 968 after the effective date of this program<sup>4</sup>.
- 969
- 970 (a) Handheld lasers that are tested in order to be used in demonstration or presentation
- 971 settings shall be confirmed by OSHE to operate as Class 3R or less, visible
- 972 wavelengths only.
- 973
- 974 (b) Devices that meet the requirements of this suborder shall be labeled as such and may
- 975 be used by personnel with no further review or training.
- 976
- 977 (c) Devices that do not meet the requirements of this suborder, as it pertains to handheld
- 978 lasers, shall be labeled as such. They are not to be used in demonstration or
- 979 presentation settings without hazard review and shall only be used by appropriately
- 980 trained personnel.

---

<sup>4</sup> 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.

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

983

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

985

986 (a) Another individual; or

987

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

989

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

991

992 (a) Directly viewed; or

993

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

996

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

998

999 (1) Individuals who sustain an injury or suspect an injury from a laser exposure shall follow  
1000 OU procedures for receiving medical examination and care.

1001

1002 (2) Under all circumstances, if an ocular (*eye*) exposure incident occurs, the affected  
1003 individual(s) shall seek treatment from an **ophthalmologist** or **retinologist** as soon as  
1004 practical.

1005

1006 i. Training

1007

1008 (1) Training shall be provided, documented, and recorded in accordance with the  
1009 requirements of the NIST S 7101.23: *Safety Education and Training*.

1010

1011 (2) Individuals who work with invisible Class 3R, Class 3B, and Class 4 lasers shall receive  
1012 the following training:

1013

1014 (a) On-Line training provided by OSHA for laser users that covers basic information to  
1015 allow them to begin work in a supervised fashion; and

1016

1017 (b) Instructor-led training provided by OSHA on Laser Safety Awareness for Laser-Users  
1018 to be taken when next available for the new laser-user; and

1019

1020 (c) Activity-specific on-the-job training required by applicable hazard reviews.

- 1021 (3) Division Laser Safety Representatives (DLSRs) shall receive the following training to  
1022 support their responsibilities:  
1023  
1024 (a) Laser Hazard Analysis Training to cover:  
1025  
1026 i. Interpretation of the ANSI Z136 Standards for exposure limit calculations;  
1027  
1028 ii. Calculation of Maximum Permissible Exposure; and  
1029  
1030 iii. Calculation of Optical Density values for laser protective eyewear.  
1031  
1032 (b) It is strongly recommended that DLSRs take Work and Worker Authorization Based  
1033 on Hazard Review training to become familiar with application of controls to mitigate  
1034 potential hazards.  
1035  
1036 (4) Individuals that may occasionally, in the course of their duties, be called to enter a laser  
1037 lab unescorted but are not generally expected to use or work in the vicinity of lasers, shall  
1038 receive OSHE provided Laser Safety Awareness training for non-users.  
1039  
1040 (a) Examples of such staff shall include, but may not be limited to:  
1041  
1042 i. First responders – Police, Fire, *etc.*  
1043  
1044 (5) The NIST LSO and DLSO shall receive documented Laser Safety Officer Training to  
1045 support their responsibilities.  
1046  
1047

## 1048 7. DEFINITIONS

- 1049 a. Accessible (Beam) – If one can gain access to laser radiation in excess of the MPE without  
1050 the elimination or bypassing of an approved control, then it shall be considered “accessible”.  
1051  
1052 b. Accessible Emission Limit (AEL) – The maximum accessible emission level permitted  
1053 within a particular laser class.  
1054  
1055 c. Accessible Laser Radiation – Laser radiation emitted from a laser that is compared with the  
1056 AEL to determine its hazard class. Includes accessible radiant energy and power.  
1057  
1058 d. Administrative Control Measure – Control measures incorporating administrative means  
1059 (*e.g.*, training, safety approvals, LSO designation, and standard operating procedures) to  
1060 mitigate the potential hazards associated with laser use.

- 1061 e. Aperture – An opening, window, or lens through which optical radiation can pass. The  
1062 aperture limits the energy or power for measurement or exposure.  
1063
- 1064 f. Authorized Personnel – Individuals approved by management to operate, maintain, service,  
1065 or install laser equipment.  
1066
- 1067 g. Beam – A collection of light/photonic rays characterized by direction, diameter (or  
1068 dimensions), and divergence (or convergence).  
1069
- 1070 h. Blink Reflex or Aversion Response – The closure of the eyelid or movement of the head to  
1071 avoid exposure to a noxious stimulant of bright light. It generally occurs within 0.25 seconds.  
1072
- 1073 i. Broad-Spectrum Laser – Any laser that is simultaneously emitting a continuum of radiation  
1074 over an intentionally broad spectral range. For the purposes of this suborder, lasers emitting a  
1075 continuous spectrum that spans greater than 200 nm shall be considered Broad-Spectrum.  
1076 Such lasers may include, but are not limited to: Super-continuum, frequency combs,  
1077 amplified spontaneous emission sources.  
1078
- 1079 j. Collateral Radiation – Any electromagnetic radiation, except laser radiation, emitted by a  
1080 laser. This does not include laser target interaction radiation (re-radiation).  
1081
- 1082 k. Collecting Optics – Lenses or optical instruments having magnification and thereby  
1083 producing an increase in energy or power density. Such devices may include telescopes,  
1084 binoculars, microscopes, or loupes.  
1085
- 1086 l. Continuous Wave (CW) – The output of a laser, operated in a continuous rather than a pulsed  
1087 mode. For purposes of safety evaluation, a laser that is operated with a continuous output for  
1088 a period of 0.25 seconds or greater is typically regarded as a CW laser.  
1089
- 1090 m. Control Measure – A means to mitigate potential hazards associated with the use of lasers.  
1091 Within the hierarchy of controls, they are, in order of considered efficacy: Elimination,  
1092 Substitution, Engineering Controls, Administrative Controls, and PPE. For the purposes of  
1093 this suborder, it is already presumed that the hazard in question (Lasers) cannot be eliminated  
1094 or substituted. The remaining control measures are: engineering, procedural (administrative),  
1095 and personal protective equipment (PPE).  
1096
- 1097 n. Diffuse Reflection – Change of spatial distribution of a beam of radiation when it is reflected  
1098 in many directions by a surface or by a medium. Diffuse reflections are less hazardous than  
1099 specular reflections for a given beam.  
1100

- 1101 o. Electromagnetic Radiation – The flow of energy consisting of orthogonally vibrating electric  
1102 and magnetic fields lying transverse to the direction of propagation. Gamma rays, X-rays,  
1103 ultraviolet, visible, infrared, and radio waves occupy various portions of the electromagnetic  
1104 spectrum and differ only in frequency, wavelength, and photon energy.  
1105
- 1106 p. Embedded Laser – An enclosed laser that has a higher classification than the larger system in  
1107 which it is incorporated, where the system's lower classification is appropriate due to the  
1108 engineering features limiting accessible emission.  
1109
- 1110 q. Enclosed Laser – A laser that is contained within a protective housing of itself or of the laser  
1111 or system in which it is incorporated. Opening or removal of the protective housing provides  
1112 additional access to laser radiation above the applicable MPE than possible with the  
1113 protective housing in place.  
1114
- 1115 r. Energy – The capacity for doing work. Energy content is commonly used to characterize the  
1116 output from pulsed lasers and is generally expressed in Joules (J).  
1117
- 1118 s. Engineering Controls – Methods of protecting others from exposure to laser radiation that  
1119 requires no training on the behalf of those who may be exposed, e.g., interlocks and barriers.  
1120
- 1121 t. High Energy Laser (HEL) – A high power CW laser, high energy pulsed laser, or high peak  
1122 power pulsed laser.  
1123
- 1124 u. Infrared Radiation – Electromagnetic radiation with wavelengths that lie within a range of  
1125 700 nm to 1 mm.  
1126
- 1127 v. Irradiance (E) – Radiant power incident per unit area upon a surface, expressed in watts per  
1128 square centimeter ( $W/cm^2$ ).  
1129
- 1130 w. LASER – A device that produces an intense, coherent, directional beam of light by  
1131 stimulated emission of electronic or molecular transitions to lower energy levels. An  
1132 acronym for “**L**ight **A**mplification by **S**timulated **E**mission of **R**adiation.”  
1133
- 1134 x. Laser Barrier – A device used to block or attenuate incident direct or diffuse laser radiation.  
1135 Laser barriers are frequently used during times of service to the laser system when it is  
1136 desirable to establish a boundary for a controlled laser area.  
1137
- 1138 y. Laser Classification – An indication of the beam hazard level of a laser during normal  
1139 operation, or the determination thereof. The hazard level of a laser is represented by a

1140 number or a numbered capital letter. The laser classifications are Class 1, Class 1M, Class 2,  
1141 Class 2M, Class 3R, Class 3B and Class 4.

1142

1143 (1) Class 1 Lasers – Any laser or laser product containing a laser that cannot emit laser  
1144 radiation at levels that are known to cause eye or skin injury during normal operation.  
1145 This does not apply to maintenance or service activities requiring access to Class 1  
1146 enclosures containing higher class lasers.

1147

1148 (2) Class 1M Lasers – A subcategory of Class 1 lasers is Class 1M. This classification  
1149 describes laser products that are considered incapable of producing hazardous exposure  
1150 unless viewed with collecting optics. These lasers are exempt from control measures  
1151 unless optically aided viewing is possible.

1152

1153 (3) Class 2 Lasers – Laser products that emit solely in the visible portion of the spectrum  
1154 (400 to 700 nm) at power levels of 1 mW or less. Eye protection is normally afforded by  
1155 the natural aversion response, *i.e.*, the human eye will blink within an exposure time  $T$   
1156 less than 0.25 s when exposed to Class 2 laser light. These products are exempt from  
1157 control requirements under normal operating conditions. As a matter of good practice,  
1158 doors should be closed, and appropriate hazard signage may be posted.

1159

1160 (4) Class 2M Lasers – A subcategory of Class 2 lasers is Class 2M. This classification  
1161 describes visible lasers that are safe to view by the unaided eye for 0.25 s. Like Class 1M,  
1162 they are unsafe under some viewing conditions with optical aids. These lasers are exempt  
1163 from control measures unless optically aided viewing is possible.

1164

1165 (5) Class 3 Lasers – Class 3 lasers may be hazardous under direct and specular reflection  
1166 viewing conditions, but are normally not a diffuse reflection or fire hazard. The LSO (or  
1167 delegate) can provide guidance or assistance for such classifications and appropriate  
1168 control measures. Refer to Section 6d for control requirements. There are two subclasses  
1169 within this classification:

1170

1171 (a) Class 3R lasers are potentially hazardous under some direct and specular reflection  
1172 viewing conditions if the eye is appropriately focused and stable. Class 3R lasers have  
1173 CW power levels no greater than 5 times the safe exposure limit. For visible lasers  
1174 (400 nm to 700 nm), it is 5 times the Class 2 limit, or 5 mW. For invisible lasers  
1175 (<400 nm or >700 nm), it becomes 5 times the Class 1 limit, which varies as a  
1176 function of wavelength. Pulsed lasers have varying limits, dependent on wavelength,  
1177 pulse duration, and repetition rate. Class 3R is roughly equivalent to earlier  
1178 classification designations of "Class 3A", "3a" or "IIIa". The most notable exception  
1179 is for divergent-beam laser diodes and fiber-coupled lasers. Many such devices that

1180 were previously classified as 3A may be Class 2M, or even Class 1M, in the new  
1181 classifications.

1182 For the purposes of this suborder, Class 3R lasers operating outside the visible  
1183 spectrum (400 nm to 700 nm), shall be treated as Class 3B lasers, with the controls  
1184 that are required for that classification.

1185  
1186 (b) Class 3B lasers may be hazardous under direct and specular reflection viewing  
1187 conditions. In general, they do not pose a significant skin hazard except for higher  
1188 powered lasers operating at certain wavelength regions. Example: Class 3B visible  
1189 lasers have power levels nominally greater than 5 mW and less than 0.5 W under CW  
1190 operation. Under pulsed operation, ANSI Z136.1 must be consulted as the upper  
1191 threshold is wavelength dependent.

1192  
1193 (6) Class 4 Lasers – Class 4 lasers include all lasers that pose a hazard to the eye or skin from  
1194 the direct or specular beam and may pose a diffuse reflection or fire hazard. Class 4 lasers  
1195 may also produce LGAC and/or hazardous plasma radiation. These systems produce  
1196 optical radiation at power and/or energy levels in excess of lasers designated as Class 3B  
1197 or below.

1198  
1199 z. Laser Generated Air Contaminants (LGAC) – Chemicals, compounds and/or particulate  
1200 material that is generated as a result of laser-matter interactions such as, but not limited to:  
1201 ablation, cutting, welding, *etc.*

1202  
1203 aa. Laser Control Area (LCA) – An area within which there is the possibility of exposure to laser  
1204 radiation in excess of the MPE. Perimeter boundaries are established to ensure there is no  
1205 hazardous or excessive exposure outside of the LCA, and access is controlled to ensure only  
1206 Authorized Users are permitted within the LCA when the laser hazard is present.

1207  
1208 bb. Laser Pointer – Typically a handheld laser to be used in demonstrations, presentations, or  
1209 other non-laboratory or non-experimental activities. These products shall be Class 1, Class 2,  
1210 or Class 3R and only operate in the visible spectrum (400 nm to 700 nm).

1211  
1212 cc. Laser Product – Any manufactured product or assemblage of components that constitutes,  
1213 incorporates, or is intended to incorporate a laser. A laser intended for use as a component of  
1214 an electronic product is itself considered a laser product.

1215  
1216 dd. Laser Safety Officer (LSO) – One who has authority and responsibility to monitor and  
1217 enforce the control of laser hazards and effect the knowledgeable evaluation and control of  
1218 laser hazards.

1219

- 1220 ee. Laser System – An assembly of electrical, mechanical, and optical components that includes  
1221 a laser.  
1222
- 1223 ff. Maximum Permissible Exposure (MPE) – The level of laser radiation to which a person may  
1224 be exposed without hazardous effect or adverse biological changes to eye or skin. MPE is  
1225 expressed in terms of either radiant exposure (Joules/cm<sup>2</sup>) or irradiance (Watts/cm<sup>2</sup>). The  
1226 criteria for MPE are detailed in Section 8 of ANSI Z136.1.  
1227
- 1228 gg. Multi-wavelength laser – Any laser that is capable of emitting multiple discrete wavelengths  
1229 simultaneously.  
1230
- 1231 hh. Nominal Hazard Zone (NHZ) – The workspace within which the level of the direct, reflected,  
1232 or scattered radiation during normal operation exceeds the applicable MPE. Exposure levels  
1233 beyond the boundary of the NHZ are below the appropriate MPE level.  
1234
- 1235 ii. Non-Beam Hazards (NBH) – All hazards arising from the presence of a laser, excluding  
1236 direct human exposure to direct or scattered laser radiation.  
1237
- 1238 jj. Optically Aided Viewing – Viewing with a telescopic (binocular) or magnifying optic. Under  
1239 certain circumstances, viewing with an optical aid can increase the hazard from a laser beam.  
1240
- 1241 kk. Optical Density (OD) – Logarithm to the base ten of the reciprocal of the transmittance:  $OD$   
1242  $= \log_{10} (1/T_{\lambda})$ , where  $T_{\lambda}$  is the transmittance at the wavelength of interest.  
1243
- 1244 ll. Personal Protective Equipment (PPE) – Personal safety protective devices used to mitigate  
1245 hazards associated with laser use (*e.g.*, laser eye protection, protective clothing, and gloves).  
1246
- 1247 mm. Plasma Radiation – Laser target interaction radiation (LTIR) generated by a plasma.  
1248
- 1249 nn. Power – The rate at which energy is emitted, transformed, or received in Watt or  
1250 Joule/second. Also called the radiant power.  
1251
- 1252 oo. Protective Housing – An enclosure that surrounds the laser and prevents access to laser  
1253 radiation above the applicable MPE. The aperture through which the useful beam is emitted  
1254 is not part of the protective housing. The protective housing limits access to other associated  
1255 radiant energy emissions and to electrical hazards associated with components and terminals  
1256 and may enclose associated optics and a workstation.  
1257
- 1258 pp. Pulse Duration – The duration of a laser pulse, usually measured as the time interval between  
1259 the half-power points on the leading and trailing edges of the pulse.
-



- 1260 qq. Pulse-Repetition Frequency (PRF) – The number of pulses occurring per second, expressed  
1261 in hertz.  
1262
- 1263 rr. Pulsed Laser – A laser that delivers its energy in the form of a single pulse or a train of  
1264 pulses. The duration of a pulse is regarded to be less than 0.25 seconds.  
1265
- 1266 ss. Radiant Exposure (H) – Surface density of the radiant energy received ( $J/cm^2$ ).  
1267
- 1268 tt. Radiant Flux (F) – Power emitted, transferred, or received in the form of radiation, expressed  
1269 in Watts (also called radiant power).  
1270
- 1271 uu. Specular Reflection – A mirror-like reflection typically resulting from a smooth, flat surface.  
1272 Specular reflections are more hazardous than diffuse reflections for a given beam.  
1273
- 1274 vv. Standard Operating Procedure (SOP) –A written step-by-step procedure or operational  
1275 protocol used to document how a given task **must** be carried out to ensure safe operation.  
1276 SOPs are generally needed when failure to follow a prescribed set of steps results in  
1277 significant increase in risk.  
1278
- 1279 ww. Transmittance – The ratio of total transmitted radiant power to the total incident radiant  
1280 power.  
1281
- 1282 xx. Ultraviolet Radiation (Light) – Electromagnetic radiation with wavelengths smaller than  
1283 those of visible radiation; for the purpose of laser safety, 180 nm to 400 nm.  
1284
- 1285 yy. Visible Radiation (Light) – Electromagnetic radiation that can be detected by the human eye.  
1286 This term is commonly used to describe wavelengths that lie in the range of 400 nm to 700  
1287 nm.  
1288
- 1289 zz. Watt – The unit of power or radiant flux. 1 Watt = 1 Joule per second.  
1290
- 1291 aaa. Wavelength – The distance between two successive points on a periodic wave that have  
1292 the same phase.  
1293  
1294
- 1295 **8. ACRONYMS**
- 1296 a. AEL – Accessible Emission Limit  
1297
- 1298 b. ANSI – American National Standards Institute  
1299

- 1300 c. CSO – Chief Safety Officer
- 1301
- 1302 d. CW – Continuous Wave
- 1303
- 1304 e. DLSO – Deputy Laser Safety Officer
- 1305
- 1306 f. DLSR – Division Laser Safety Representative
- 1307
- 1308 g. DSR – Division Safety Representative
- 1309
- 1310 h. HEL – High Energy Laser
- 1311
- 1312 i. IR – Infrared
- 1313
- 1314 j. LCA – Laser Control Area
- 1315
- 1316 k. LGAC – Laser Generated Air Contaminants
- 1317
- 1318 l. LSAC – Laser Safety Advisory Committee
- 1319
- 1320 m. LSO – Laser Safety Officer
- 1321
- 1322 n. MPE – Maximum Permissible Exposure
- 1323
- 1324 o. NIST – National Institute of Standards and Technology
- 1325
- 1326 p. OD – Optical Density
- 1327
- 1328 q. OSHE – Office of Safety, Health, and Environment
- 1329
- 1330 r. OU – Operating Unit
- 1331
- 1332 s. PPE – Personal Protective Equipment
- 1333
- 1334 t. SOP – Standard Operating Procedure
- 1335
- 1336 u. UV – Ultraviolet
- 1337
- 1338

1339 **9. RESPONSIBILITIES**

1340 Roles and responsibilities common to all NIST OSH suborders can be found in Section 8 of  
1341 NIST O 7101.00: *Occupational Safety and Health Management System*. The roles and  
1342 responsibilities specific to this suborder are as follows:

- 1343
- 1344 a. OU Directors are responsible for:
- 1345
- 1346 (1) Establishing policies and procedures, as needed, for the requirements of this program to  
1347 be met as it applies to their employees and covered associates and to lasers operated  
1348 during their OU operations and ensuring that those policies and procedures are  
1349 implemented; and
- 1350
- 1351 (2) Ensuring subordinate managers have the authority, resources, and training needed to  
1352 implement OU-established policies and procedures.
- 1353
- 1354 b. CSO shall be responsible for designating NIST employees to serve as the LSO and DLSO.
- 1355
- 1356 c. Authorized Users are responsible for:
- 1357
- 1358 (1) Ensuring their own safety and the safety of those around them, including new users under  
1359 observation;
- 1360
- 1361 (2) Operating lasers in accordance with this laser safety program at all times and ensuring  
1362 that all requirements (Section 6) of this Suborder are met;
- 1363
- 1364 (3) Seeking guidance for situations not covered by this program, or that require clarification;
- 1365
- 1366 (4) Notifying safety representatives and supervisors of any unsafe situations or practices, as  
1367 well as missing or inoperative laser safety equipment;
- 1368
- 1369 (5) Being vigilant for scope creep in terms of the boundaries established in the hazard  
1370 review; and
- 1371
- 1372 (6) Notifying the DLSR of all new or altered laser installations.
- 1373
- 1374
- 1375

- 1376 d. Division Chiefs (or Equivalent)<sup>5</sup> are responsible for:  
1377  
1378 (1) Implementing this program as it applies to activities involving their personnel in  
1379 accordance with any applicable OU-established policies and procedures;  
1380  
1381 (2) Allocating budgetary and other resources capable of ensuring the health and safety of  
1382 employees, covered associates, and visitors in divisional work areas;  
1383  
1384 (3) Providing support to divisional group leaders, safety personnel, employees, and covered  
1385 associates in carrying out their responsibilities with respect to implementing the  
1386 requirements of this suborder and managing lasers within the division;  
1387  
1388 (4) Acting on all incidents involving lasers and related safety concerns reported by divisional  
1389 personnel quickly and completely to protect employees and covered associates from the  
1390 health and physical hazards presented by lasers in divisional work areas; and  
1391  
1392 (5) Designating the Division Laser Safety Representative(s) (DLSR). This designation  
1393 acknowledges that the Division Chief has an appropriate degree of confidence, based on  
1394 personal knowledge, observation, or reliable input from others, that the personnel to be  
1395 designated as DLSR:  
1396  
1397 (a) Have the knowledge, skills, and abilities to evaluate the laser operations, evaluate  
1398 hazards and determine safety controls; and  
1399  
1400 (b) Fully understand the boundaries/conditions imposed on the activity by the activity  
1401 hazard review, the need to work within those boundaries/conditions, and the process  
1402 for requesting work that falls outside of those boundaries/conditions.  
1403  
1404 e. Line Management is responsible for:  
1405  
1406 (1) Ensuring required training has been completed by affected employees and covered  
1407 associates;  
1408 (2)  
1409  
1410 (3) Approving employees and associates as Authorized Users through the Hazard Review  
1411 process to work in or around laser hazards in a laser control area; and  
1412

---

<sup>5</sup> Some NIST OUs do not have Division Chiefs; these OUs shall designate other individuals to carry out these responsibilities.

- 1413 (4) Providing oversight as necessary aimed at ensuring that employees and covered  
1414 associates who operate lasers do so in accordance with this suborder.  
1415
- 1416 f. Division Laser Safety Representatives (DLSRs) are responsible for:  
1417
- 1418 (1) Completing all training per the requirements of this suborder prior to engaging in DLSR  
1419 responsibilities;  
1420
- 1421 (2) As an element of the hazard review process, including new reviews, revisions, and  
1422 renewals (not to exceed a three-year interval), determining whether their participation is  
1423 warranted based on identified hazards and/or the extent of change(s) to the activity;  
1424
- 1425 (a) If their participation is warranted or otherwise required by OU or Division policy,  
1426 actively participating in hazard reviews.  
1427
- 1428 (3) Conducting periodic review of any Division-level laser safety policy or supplemental  
1429 programs.  
1430
- 1431 (4) Bringing all potential laser safety issues to the attention of appropriate parties and  
1432 informing the Division Chief of any unresolved issues;  
1433
- 1434 (5) Serving as a delegate of the NIST LSO for the following responsibilities:  
1435
- 1436 (a) Providing guidance, oversight, and administration necessary to help ensure Division  
1437 compliance with this Suborder;  
1438
- 1439 (b) Participating in the Hazard Review of new or altered laser installations;  
1440
- 1441 i. Providing hazard analysis for laser-related reviews  
1442
- 1443 (i) Establishing exposure limits  
1444
- 1445 (ii) Establishing OD requirements for PPE  
1446
- 1447 (iii) Recommending to management for Hazard Review approval based on  
1448 controls applied in the Hazard Review process.  
1449  
1450  
1451  
1452

- 1453 g. NIST Laser Safety Officer (LSO) is responsible for:  
1454  
1455 (1) Forming committees and establishing delegates as needed to successfully implement the  
1456 laser safety program;  
1457  
1458 (2) Providing laser safety training opportunities, and providing assistance to the DLSRs;  
1459  
1460 (3) Participating in Division-level and OU-level laser hazard reviews and safety inspections  
1461 upon request;  
1462  
1463 (4) Providing guidance on compliance with 21 CFR 1040 regarding introduction of lasers  
1464 into commerce as needed;  
1465  
1466 (5) Providing guidance on testing of laser protective eyewear for conditions not met by  
1467 manufacturers specifications; and  
1468  
1469 (6) Providing guidance on FAA and other agency communication and oversight as it pertains  
1470 to outdoor laser operations.

- 1471  
1472 h. NIST Deputy Laser Safety Officer (DLSO) is responsible for:  
1473  
1474 (1) Serving as a delegate of the NIST LSO for the following responsibilities:  
1475  
1476 (a) Assisting in the NIST level administration of this program;  
1477 (2) Assisting in providing laser safety training opportunities, and providing assistance to the  
1478 DLSRs;  
1479  
1480 (3) Participating in Division-level and OU-level laser hazard reviews and safety inspections  
1481 upon request.

1482  
1483  
1484 **10. AUTHORITIES**

1485 There are no authorities specific to this suborder alone.  
1486

1487  
1488 **11. DIRECTIVE OWNER**

1489 Chief Safety Officer  
1490  
1491  
1492

1493 **12. APPENDICES**  
1494 A. Revision History  
1495 B. Signage  
1496

1497  
1498

**Appendix A. Revision History**

Version No.	Approval Date	Effective Date	Brief Description of Change; Rationale
1	07/31/2019		<ul style="list-style-type: none"> <li>• None – Initial document</li> </ul>
2	05/09/2022	06/30/2023	<ul style="list-style-type: none"> <li>• Section 5 – links were updated and the Out of Service safety program was added.</li> <li>• 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.</li> <li>• Administrative updates - Footer updated to new page number format and version number, and updated Revision History table to use version number.</li> <li>• NOTE: Effective date was originally TBD due to the COVID-19 pandemic. It was updated on 4/17/23.</li> </ul>

1499  
1500



1501 **Appendix B: Examples of Laser Hazard Signs**  
 1502 Laser hazard signs shall be posted outside of laboratories containing Class 3B, invisible 3R  
 1503 or Class 4 lasers or laser systems. Laser hazard signs are optional for laboratory containing  
 1504 visible Class 3R, and Class 2 lasers. Warning signs are not required for Class 1 lasers. The  
 1505 type, wavelength, and power (or pulse energy, duration, and repetition rate) of each laser  
 1506 shall be listed. The highest classification must be used to list all the lasers. For example, if a  
 1507 laboratory contains both Class 2 and 4 lasers, the Class 4 sign shall be used. Examples of the  
 1508 required signs are shown below (intended nominal size: 11" × 8.5"). Templates for common  
 1509 laser-warning signs are posted on the NIST safety website.

1510 Table 1: Precautionary statements required to be on laser labels and hazard signs.  
 1511  
 1512

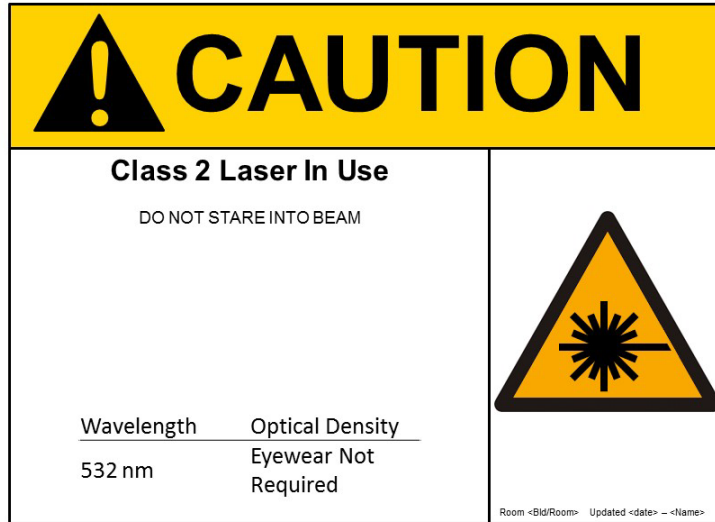
Laser Classification	Recommended Precautionary Statement
Class 1	None Required
Class 1M	LASER RADIATION – DO NOT VIEW DIRECTLY WITH OPTICAL INSTRUMENTS
Class 2	LASER RADIATION – DO NOT STARE INTO BEAM
Class 2M	LASER RADIATION – DO NOT STARE INTO THE BEAM OR VIEW DIRECTLY WITH OPTICAL INSTRUMENTS
Class 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

1513  
 1514

1515  
1516  
1517  
1518  
1519  
1520

**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.



1521  
1522

1523 **Warning**

1524  
1525  
1526  
1527  
1528  
1529  
1530

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.



1531



1532  
1533  
1534

1535  
 1536  
 1537  
 1538  
 1539  
 1540  
 1541  
 1542  
 1543

**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.



1544  
 1545  
 1546

1547  
1548  
1549  
1550  
1551  
1552  
1553  
1554

**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.



1555  
1556

1557  
1558  
1559  
1560  
1561  
1562

**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.



1563  
1564