



Laser Safety Task Group (LSTG) Report

TO: EFCOG Laser Safety Task Group Members
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SUBJECT DOE EFCOG Laser Safety Task Group Benchmark Study of ANSI
Z136.1-2014 Controls Requirements
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Preamble

To assist harmonization of best laser safety practices across the DOE Complex, a working group was commissioned by the Laser Safety Task Group (LSTG) of EFCOG to benchmark some of the controls requirements of ANSI Z136.1-2014. This work addresses a recommendation in a 2014 LSTG report, evaluating this ANSI standard (see Reference 1), to perform such a study. The group, led by Jamie King (LLNL), chose thirteen topics to focus on:

- Laser Controlled Area (LCA) Warning Device
- Emergency Stop Button
- Remote Interlock Connector
- Laser Safety Officer Training
- Standard Operating Procedure (SOP)
- Skin Personal Protective Equipment (PPE) (Ultraviolet [UV])
- Skin Exams (UV)
- Medical Baseline Eye Exam
- Full Protection Eyewear
- Alignment Eyewear
- Master Key
- Cover Interlock for a Class 1 Enclosure and Protective Housing
- Beam Stop/Attenuator

The topics were selected following analysis of a 2015 survey sent out to the DOE Laboratories. The survey results, as they pertain to this report, can be found in Appendix A along with the current Z136.1-2014 requirements. This survey reviewed current program requirements at the DOE sites. The results showed a wide variation in some controls requirements at the Labs, which helped motivate this study to improve the consistency in these requirements.

This working group developed a set of recommended program policy requirements for each of the 13 controls described above and then conducted another survey with the DOE Labs asking whether the LSOs at the Labs agreed with the recommended policy statements and associated rationale. Results from this 2016 survey can be found in Appendix B. They generally show good consensus on the recommended policy requirements and much better agreement than was achieved in the 2015 survey reported in Appendix A. In response to the survey input, some updates to the recommended controls requirements and their associated rationale were made; these updates are discussed in Appendix B.

This report should not be viewed as an attempt to set policy as this is left up to each of the individual contractor-operated Laboratories and their DOE oversight.

This report provides guidance to the DOE laser community on how to incorporate ANSI Z136.1-2014 requirements into their laser safety programs. The control requirements contained within are written so that they can easily be used in DOE site laser safety manuals.

The motivation for the report results in part from 3 factors concerning Z136.1-2014:

1. A lack of specificity for certain controls requirements.
2. A lack of clarity for certain controls requirements.
3. Changes in controls requirements between the 2000, 2007, and 2014 revisions.

This report includes a Definitions Section and a Requirements Section, which includes a rationale for each recommended requirement and notes any deviation from the Z136.1-2014 requirement. The Requirements Section assumes a DOE Facility with a laser program as follows:

1. More than one Class 3B or Class 4 LCA, and the LCAs often have more than one Class 3B or Class 4 laser.
2. A typical laser lab has:
 - a. A contained indoor LCA (enclosed within a room).
 - b. A single entrance.
 - c. A Safety Interlock System with an access control panel at the entrance.
 - d. All lasers located within the LCA.

A typical laser lab, on which this report is based, is shown in Figures 1 and 2.

Figure 1 shows the LCA in orange bounded by four walls. On the front wall is the entry door with an associated laser hazard sign and an electronic laser status warning device.

Figure 2 shows the LCA with front wall removed. The Nominal Hazard Zone (NHZ) is denoted in yellow. The orange part of the LCA near the entry is protected by a barrier wall and is considered a “safe” location outside the NHZ where one would put on or remove laser protective eyewear (LPE) and any other required PPE.

Figure 1.

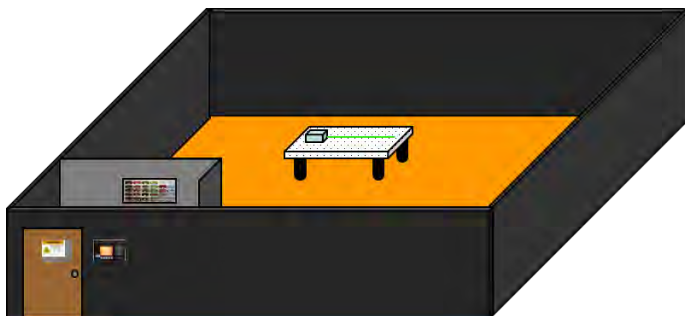


Figure 2.

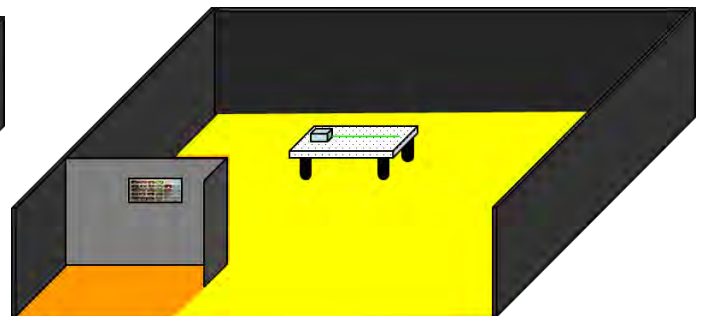


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1.0 Definitions

Alignment Eyewear - Protective eyewear for visible wavelengths with a reduced optical density (OD) from full protection.

Baseline Eye Exam - This exam is performed by occupational health persons who are designated by the Occupational Medical Director. It includes: visual acuity, Amsler grid, and ocular history. Other optional tests may include color vision and retinal imaging.

CDRH – Center for Devices and Radiological Health.

Class 1 Enclosure - No laser beams or diffuse reflections within the enclosure can escape from it at levels above the maximum permissible exposure (MPE).

Cover Interlocks for Class 1 Enclosures and Protective Housings - When the cover of a Class 1 enclosure or a protective housing is removed, this interlock disables any additional accessible Class 3B or Class 4 laser hazard(s) to below the MPE.

Defeatable Interlock - A mechanism that allows for the bypassing of the interlock feature when a cover/panel is removed for special operations, e.g., laser alignment, maintenance.

Emergency Stop (OFF) Device - When activated, this ensures any laser radiation within the LCA is below the Class 3R accessible emission limit (AEL).

Failsafe or Redundant Interlocks - Do not permit an unsafe condition if there is a single component failure.

Full Protection Eyewear - Protective eyewear that attenuates the laser beam to a safe level below the MPE.

IEC – International Electrotechnical Commission

Laser Source Beam Stop/Attenuator - Prevents access to laser radiation in excess of applicable MPE.

Laser Controlled Area (LCA) - A laser use area where the occupancy and activity of those within is controlled and supervised. This area may be defined by walls, barriers, or other means. Within this area, potentially hazardous beam exposure is possible.

Laser Safety Officer (LSO) - For the purpose of this document the LSO is the site-wide LSO with responsibility for the laser safety program at the site.

LCA Warning Device - Electronic illuminated indicator that displays when laser radiation above Class 3R AEL may be present within the LCA.

LGAC – Laser Generated Air Contaminate

Master Key - A device (typically a mechanical key) that when removed prevents associated laser(s) from emitting laser radiation above the MPE.

Maximum Permissible Exposure (MPE) - The level of laser radiation to which an unprotected person may be exposed without adverse biological changes in the eye or skin.

Nominal Hazard Zone (NHZ) - The space within which the level of the direct, reflected, or scattered radiation may exceed the applicable MPE. Exposure levels beyond the boundary of the NHZ are below the applicable MPE.

Non-defeatable Interlock - Contains no means to bypass the interlock feature and is always active.

Occupational Medical Director - For the purpose of this document the Occupational Medical Director is the individual with responsibility for the occupational medical program at the site.

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.

Protective Housing - Encloses one or more laser wavelengths so the wavelength(s) cannot escape the enclosure at levels above the MPE. A protective housing does not include the aperture for the output beam.

Remote Interlock Connector - Part of a laser source that interfaces with an LCA safety interlock system. When the connector contacts are open or faulted, the laser source is disabled from emitting laser radiation above the MPE.

Shall - Mandatory

Should - Advisory (Recommended)

Skin Exam - This includes: observation of dermatological abnormalities, history of skin problems, current complaints of skin problems, and use of potentially photosensitizing drugs.

Skin PPE - Skin protection that reduces skin exposure to levels below the MPE.

Standard Operating Procedure (SOP) - A formal written description of the safety and administrative procedures to be followed in performing a specific task.

2.0 Requirements

Z136.1-2014 has many requirements which are “should” for Class 3B and “shall” for Class 4. This report generally makes the requirements “shall” for both Class 3B and Class 4. Alternate controls can be used in certain applications such as 20 mW continuous wave visible lasers or configurations with very simple beam delivery and stable configuration. Alternate controls may include no unattended operation, simple beam paths and perimeter barriers, and no out-of-plane beams.

Requirements recommended in this report are at least as stringent as in ANSI Z136.1-2014.

2.1 LCA Warning Device (Class 3B or Class 4)

An LCA Warning Device *shall* be installed at the LCA entryway so it is visible prior to entry. It *shall* also be installed inside the LCA, where it *should* be easily viewable to persons in the LCA. It *should* be electronically interfaced to a laser power supply, safety shutter, or safety interlock system.

An exception to the LCA Warning Device requirements above is permitted in cases where the Laser Safety Officer (LSO) determines that the NHZ within the LCA is very limited in extent. In this case the LSO *shall* require an NHZ warning device, sign or label to clearly communicate where laser radiation may be present above Class 3R levels.

Rationale - Persons entering an LCA need adequate warning prior to entering if there may be laser radiation present above Class 3R levels. Inside the LCA, the laser operation status needs to be readily apparent; a laser's emission indicator alone is usually not adequate. This engineered control ensures worker protection rather than relying on a worker to announce the current laser status or a changing laser condition.

Deviations from Z136.1-2014:

- *Z136.1 gives requirement as **should** for Class 3B.*
- *Z136.1 states separate requirements for an Area Warning Device (visible prior to entry) and a Laser Radiation Emission Warning (visible inside the LCA).*
- *Z136.1 does not describe the exception noted for NHZs with limited extent.*
- *Z136.1 does not define an LCA Warning Device, but instead gives examples of visible and audible devices.*

2.2 Emergency Stop (OFF) Device (Class 3B or Class 4 LCA)

A Class 4 LCA *shall* have and a Class 3B LCA *should* have a clearly marked Emergency Stop (OFF) device.

Rationale - A clearly marked "Emergency OFF," e.g., mushroom button, is easily recognizable by personnel as the method to "safe" the laser. A marked switch on a laser power supply or even a

keystroke of a computer is generally not sufficient if emergency/rescue personnel must enter a space to secure or "safe" the laser. In addition to the Z136.1-2014 requirement, NFPA 115 Laser Fire Protection states that "a master emergency electrical shutdown switch that will immediately de-energize the laser **shall** be provided" for all Class 4 lasers.

Deviations from Z136.1-2014:

- Z136.1 has no requirement for Class 3B LCAs.
- (Z136.8-2012 does not require an Emergency Stop/Off/Shutdown provision.)

2.3 Remote Interlock Connector (Class 3B or Class 4)

Class 3B and Class 4 laser sources **should** have a remote interlock connector.

Rationale - The use of a remote interlock connector is paramount for the protection of non-laser workers. The remote interlock connector, when connected to a Safety Interlock System ensures the safety of ancillary personnel who may attempt to gain access to an LCA either through a connected entryway or interlocked enclosure panel. This can be used to implement functionality for Emergency Stop (OFF) as well as for LCA entry faults and protective housing or enclosure cover faults.

Deviations from Z136.1-2014:

- Z136.1 has no requirement. This was present in the 2007 revision.
- (Z136.8-2012 also has no requirement.)

2.4 Laser Safety Officer (LSO) Training

LSO training **shall** be provided. The training **shall** be commensurate to the highest Class of laser under the jurisdiction of the LSO and **shall** include potential hazards, control measures, medical examinations, applicable standards, and non-beam hazards. The LSO **shall** participate as a member of the DOE EFCOG Laser Safety Task Group (LSTG) and **should** obtain LSO certification with the Board of Laser Safety.

Rationale - LSO training is required by ANSI Z136.1-2014. A DOE LSO needs to join the LSTG and is invited to participate in the meetings and workshops in order to stay current with laser safety in the DOE complex. LSO certification provides evidence that the DOE LSOs are committed to being up-to-date with laser safety training and information.

Informational Note: Minimal training for an LSO is typically a commercially available 5-day Laser Safety Officer Training WITH Hazard Analysis Courses.

Deviations from Z136.1-2014:

- Z136.1 does not have a requirement for EFCOG participation or for LSO certification.

2.5 Standard Operating Procedures (SOPs) Requirements

SOPs for Class 3B and Class 4 lasers *shall* be required and approved by an LSO. Alignment procedures *shall* be included as part of the written SOP for both Class 3B and Class 4 lasers.

The SOPs *should* include the following items. If not included in the SOP they *shall* be documented elsewhere:

- i. The laser hazard parameters (power, pulse energy, pulse width, repetition rate).
- ii. OD requirements and required PPE.
- iii. Engineering and administrative controls.
- iv. A schematic of the laser controlled area including where the lasers, emergency stop buttons, and external safety shutters are located.

Rationale - Although not required by Z136.1-2014, Class 3B require an SOP due to the high hazard of said lasers at the upper end of the Class 3B classification. The listed items need to be documented so that the laser user is fully aware of all the hazards and how to control them.

Informational Note: Examples of alternative documentation could be:

- i. Local posting of the LCA schematic.
- ii. Local posting of OD and PPE requirements at entry to LCA.

Deviations from Z136.1-2014:

- Z136.1 gives requirements as *should* for Class 3B.
- Z136.1 does not specify the listed items to include in the SOP or to document elsewhere.
- (Z136.8-2012 gives requirements as *shall* for Class 3B and Class 4.)

2.6 Skin PPE Requirements

Skin protection *shall* be used if there may be UV radiation exposure above the MPE.

Rationale - Z136.1-2014 requires beam shields and skin protection for UV lasers with exposure above the MPE.

Informational Note: Consideration needs to be given for:

- i. Chronic exposures to diffuse laser radiation hazards.
- ii. The use of a full face shield in addition to gloves and long-sleeved clothing for high powered laser operations.

Deviations from Z136.1-2014:

- None

2.7 Skin Exams (UV)

Personnel **should** request a skin exam if they experience any symptoms from exposure to UV laser beams. If they are working with UV lasers and are at risk for exposure above the MPE, in particular if they have a history of photosensitivity, they **should** also request periodic skin exams.

Rationale - Z136.1-2014 recommends skin exams for employees working with UV lasers.

Deviations from Z136.1-2014:

- *Z136.1 only gives a recommendation in an informational appendix, with no “**should**” or “**shall**” requirements.*
- *(Z136.8 states that “Laser users chronically exposed to artificial sources of UV radiation should obtain an annual skin cancer screening.”)*

2.8 Medical Baseline Eye Exam

A baseline eye exam **should** be performed on laser workers prior to commencement of their laser work in NHZs where Class 3B or Class 4 laser beams are present.

Rationale - The baseline eye exam is simple:

- *No eye dilation.*
- *No ophthalmologist required.*
- *Simple tests that take <30 minutes and can generally be performed by a DOE site’s medical office.*

It is useful for the following reasons:

- Assesses “fitness for duty” and is good medical practice (EFCOG Occupational Medicine Task Group recommends it).*
 - Laser personnel will be using laser eye protection that restricts vision and need evaluation to determine if they have any vision problems that need to be addressed, e.g., outdated prescription.*
 - Some people have color vision issues. Since color coding is used for electronic signs, increased awareness for workers and supervisors is useful.*
- Helps convey emphasis on keeping your eyes safe and complying with eyewear requirements.*
- Helps establish relationship with medical office and availability of services. Can also perform quick assessment of other health issues that may present.*

Deviations from Z136.1-2014:

- *Z136.1 gives requirements as **should** be considered for both Class 3B and Class 4.*
- *(Z136.8-2012 gives requirement as **should** for both Class 3B and Class 4.)*

2.9 Full Protection Laser Eyewear

Full protection eyewear *shall* be required whenever Class 3B or Class 4 laser radiation is accessible within the NHZ, unless the LSO approves use of alignment eyewear.

Rationale - If Class 3B or Class 4 radiation is present in the lab and not confined within a Class 1 enclosure, then full protection eyewear needs to be mandatory unless LSO has approved an exception for alignment eyewear. An exemption based on other engineering and administrative controls is not justified.

Deviations from Z136.1-2014:

- *Z136.1 allows an exemption based on engineering and administrative controls.*
- *(Z136.8-2012 gives requirement as **should** for Class 3B and **shall** for Class 4 and permits the same exemption as Z136.1.)*

2.10 Alignment Eyewear

For all routine laser operations and for most laser alignment procedures, full protection eyewear *shall* be used. Alignment eyewear may only be used for specific visible wavelength alignment procedures that have been appropriately evaluated, documented, and authorized by the LSO. The minimum OD requirement for alignment eyewear *shall* be for viewing an ideal, point-source, diffuse reflection at a distance of 20 cm. Laser users *shall* be notified that alignment eyewear will not protect them against a point source intrabeam exposure.

Rationale - Alignment eyewear use must not be routine for visible lasers. If alignment eyewear were to be used routinely, a single mistake could result in an injury.

Deviations from Z136.1-2014:

- *None*

2.11 Master Key

A Master Key *shall* be provided for all Class 3B and Class 4 lasers or laser systems.

Informational Note:

- A single Master Key can be used for multiple lasers. An LCA may have a single Master Key or multiple Master Keys.*
- A common practice is for an LCA to have a safety interlock system with an associated Master Key that disables all Class 3B and Class 4 lasers within the LCA when it is removed or turned to the OFF position.*

Rationale - The Master Key provides an engineered control to enable lasers or laser systems. It can also be used as part of an administrative procedure to ensure lasers are disabled.

Deviations from Z136.1-2014:

- Z136.1 gives requirements as **should** for both Class 3B and Class 4.
- Z136.1 allows a coded access control as an alternative to a removable Master Key.

2.12 Cover Interlock for a Class 1 Enclosure or Protective Housing

Class 1 enclosure or Protective Housing covers:

- If removable during normal operation or maintenance **shall** be provided with failsafe or redundant interlocks.
- If only removed during infrequent service tasks **shall** either:
 - be interlocked (failsafe or redundant interlocks not required), or
 - be secured requiring a tool to remove.
- If defeatable interlocks are used, it **shall** not be possible to replace the cover with the interlock defeated.
- If defeatable interlocks are used, the cover **shall** have a warning label to identify this and to identify the Class and wavelength of the enclosed laser(s).

Rationale - Engineering controls are emphasized.

Informational Note:

Interlocked cover controls provide a higher level of engineering control than secured covers; and non-defeatable interlocks provide a higher level of engineering control than defeatable interlocks.

Deviations from Z136.1-2014:

- Z136.1 only describes requirements for protective housings and not for Class 1 enclosures.
- (Z136.8-2012 considers that securing with a tool is equivalent to an interlock.)

2.13 Beam Stop/Attenuator

A Class 3B and Class 4 laser or laser system **should** be provided with a beam stop or attenuator.

Rationale - This is useful for reducing a laser hazard without turning off the laser.

Informational Note:

- This can be used when the laser output is not required.

- ii. *This can be an insertable safety shutter interfaced with a safety interlock system to disable a laser hazard when there is an interlock fault.*
- iii. *This can be an intensity control for the source laser, for example by reducing the repetition rate or by reducing the excitation source.*

Deviations from Z136.1-2014:

- *Z136.1 has no requirement. This was present in the 2007 revision. (Z136.8-2012 also has no requirement.)*

References

1. LSTG Report, [*Evaluation of ANSI Z136.1-2014 and comparison with Z136.1-2007 and Z136.8-2012*](#); December 2014.
2. ANSI Z136.1-2014, *American National Standard for Safe Use of Lasers*.
3. ANSI Z136.8-2012, *American National Standard for Safe Use of Lasers in Research, Development, or Testing*.

Appendix A

2015 DOE LSTG Benchmark Survey

This section states the ANSI Z136.1-2014 requirement and provides results from 2015 DOE Complex-wide survey based on requirement being followed at the time of the survey.

A.1 LCA Warning Device (Class 3B or Class 4)

Section 4.4.2.8 Area Warning Device (Class 3B or Class 4) - A Class 3B laser controlled area **should** and a Class 4 laser controlled area **shall** have an area warning device that is visible prior to entering the area. The purpose of the area warning device is to ensure that persons who are about to enter the laser controlled area are aware that a laser is emitting or is about to begin emitting accessible laser radiation within the area.

Section 4.4.2.9 Laser Radiation Emission Warning (Class 3B or Class 4) - Within the laser controlled area, an audible or visible laser radiation emission warning device (or emission indicator) **should** be used with Class 3B, and **shall** be used with Class 4 lasers or laser systems during activation and startup. The purpose of this radiation emission warning is to ensure that persons already within the laser controlled area are aware that a laser is emitting or is about to begin emitting accessible laser radiation within the area. The most common laser radiation emission warning device is a single (red) light located on the laser or its control panel. This form of emission warning device is a requirement for any Class 3B or Class 4 laser or laser system certified for compliance with the CDRH or with IEC standards.

Survey Results: Area Warning Device - This device is visible to personnel prior to entering an LCA to give warning that a laser is emitting or about to emit accessible laser radiation above the MPE within the LCA. Requirements:

	Shall	Should	None
Class 3B	47%	27%	27%
Class 4	87%	13%	-

Survey Results: Laser Emission Warning Device - This device is used within an LCA to alert personnel when a laser is emitting accessible laser radiation above the MPE. Requirements:

	Shall	Should	None
Class 3B	13%	47%	40%
Class 4	53%	20%	27%

A.2 Emergency Stop (OFF) Device (Class 3B or Class 4 LCA)

Section 4.4.2.10.2 (Class 4)- For emergency conditions there **shall** be a clearly marked "Emergency Stop" or other appropriately marked device suitable for the intended purpose (remote controlled connector or equivalent device) of deactivating the laser or reducing the output to levels at or below the applicable MPE.

NFPA 115 “Laser Fire Protection” Requirements (Class 4) - A master emergency electrical shutdown switch that will immediately de-energize the laser *shall* be provided. The switch *shall* be located inside or outside of each room, at the facility's discretion.

Survey Results: Emergency Stop device - For emergency conditions this device deactivates the laser(s) or reduces the laser(s) output below the MPE. Requirements:

	Shall	Should	None
Class 3B	33%	33%	33%
Class 4	93%	7%	-

A.3 Remote Interlock Connector (Class 3B or Class 4)

This requirement was removed from the 2014 revision. The 2007 revision had requirement as a “should” for Class 3B and a “shall” for Class 4.

Survey Results: Remote Interlock Connector - Allows interfacing the laser(s) or laser system(s) to an entryway interlock, enclosure interlock or emergency stop button as part of an engineered safety interlock system for an LCA. Requirements:

	Shall	Should	None
Class 3B	33%	33%	33%
Class 4	80%	7%	13%

A.4 Laser Safety Officer (LSO) Training

Section 5.4 Management (employer) *shall* provide for LSO training on the potential hazards (including bioeffects), control measures, applicable standards, medical examinations (if applicable), and any other pertinent information pertaining to laser safety and applicable standards, or provide to the LSO adequate consultative services. The training *shall* be commensurate to at least the highest Class of laser under the jurisdiction of the LSO. The training *shall* also include consideration for the evaluation and control of any non-beam hazards associated with the lasers and the laser systems under the jurisdiction of the LSO.

Appendix A1.1 (normative appendix) There *shall* be a designated LSO for all circumstances of operation, maintenance, and service of a Class 3B or Class 4 laser or laser system.

Survey Results: Not part of survey.

A.5 Standard Operating Procedures (SOPs) Requirements

Section 4.4.3.1 Standard Operating Procedures (Class 3B or Class 4) - The LSO *should* require and approve written standard operating, maintenance, and service procedures (SOPs) for Class 3B lasers or laser systems. The LSO *shall* require and approve written SOPs for Class 4 lasers or laser systems. These written SOPs *shall* be maintained with the laser equipment for reference by the operator, and maintenance or service personnel (see Section 4.4.3.8).

Section 4.4.3.8 Alignment Procedures (Class 3B and Class 4) - Written SOPs outlining alignment methods *should* be approved by the LSO for Class 3B and *shall* be approved for Class 4 lasers or

laser systems. SOPs *shall* also be applicable for all classes of lasers or laser systems that contain embedded Class 3B or Class 4 lasers under conditions that would allow access during alignment procedures. Table 10: Alignment Procedures (Section 4.4.3.8) are *shall* for Class 3B and Class 4 lasers.

Survey Results: Standard Operating Procedures (SOPs) - These written procedures describe standard operation, maintenance, and servicing. They are reviewed and approved by the LSO. Requirements:

	Shall	Should	None
Class 3B	93%	7%	-
Class 4	100%	-	-

Survey Results: Standard Operating Procedures (SOPs) for Class 3B and Class 4 lasers - which items are required to be included in the SOP document (or equivalent):

Item	Shall	No requirement
Laser Hazard Parameters (power, pulse energy, pulse width, rep rate)	87%	13%
Non-Beam Hazards	100%	-
Engineering Controls	100%	-
Administrative Procedures	100%	-
Alignment Procedures	87%	13%
Laser Eyewear PPE	93%	7%
Skin PPE	93%	7%

A.6 Skin PPE Requirements

Section 4.4.4.3.1 Particular care *shall* be taken when using UV lasers or laser systems. Exposure to UV radiation *shall* be minimized by using beam shields and clothing that attenuate the radiation to levels below the applicable MPE for the specific UV wavelengths. In some laser applications, such as use of excimer lasers operating in the ultraviolet, the use of a skin cover *shall* be employed if chronic (repeated) exposures are anticipated at exposure levels at or near the applicable MPEs for skin. If the potential exists for a damaging skin exposure, particularly for ultraviolet lasers (295 nm to 400 nm) and/or laser welding/cutting application, then skin-covers and/or “sun screen” creams are recommended.

NOTE: Chronic exposure may have long-term adverse health effects, which are not fully understood at this time.

Hazardous byproducts: Special attention *shall* be given to the possibility of producing undesirable reactions in the presence of UV radiation. For example, formation of skin sensitizing agents, ozone, and LGAC (see Section 7.4). PPE *shall* be used when working with open beam Class 3B or Class 4 UV lasers. This *shall* include both eye and skin protection.

Survey Results: Skin protection requirements for UV Class 3B and Class 4 laser use.

Requirements:

Shall use when open UV beam	Shall use if may be exposure above MPE	Should use if may be exposure above MPE	No requirement
40%	47%	7%	7%

A.7 Skin Exams (UV)

Appendix F1.2 Skin Examination (*informative appendix*) - While not required for pre-placement of laser workers, skin examinations are recommended for employees with a history of photosensitivity or working with lasers emitting accessible UV radiation. Any previous dermatological abnormalities and family history are reviewed. Any current complaints concerned with the skin are noted as well as the history of medication usage, particularly concentrating on those drugs that are potentially photosensitizing. Further examination **should** be based on the type of laser radiation, above the appropriate MPEs, present in the individual's work environment.

Survey Results: Periodic (e.g., annual) Skin Exams for UV Class 3B and Class 4 laser use.

Requirements:

Shall be completed if working with UV lasers	Should be completed if working with UV lasers	Recommended if working with UV lasers	Recommended if working with UV lasers if may have exposure above MPE	No requirement
0%	7%	13%	0%	80%

A.8 Medical Baseline Eye Exam

Section 6.2- This **should** be considered for personnel exposed to Class 3B and Class 4 lasers and laser systems.

Survey Results: A baseline eye exam - performed prior to personnel beginning laser work. It includes visual acuity, Amsler grid, color vision, and ocular history. Requirements:

	Shall	Should	None
Class 3B	93%	7%	-
Class 4	100%	-	-

A.9 Full Protection Laser Eyewear

Section 4.4.4.2.1 (Class 3B or Class 4) - Eye protection devices that are specifically designed for protection against radiation from Class 3B and Class 4 lasers or laser systems **shall** be administratively required within the NHZ and their use enforced when engineering or procedural and administrative controls are not practicable.

Survey Results: Full protection eyewear - used when there is accessible laser radiation above the MPE, except when the LSO approves alignment eyewear. Requirements:

	Shall	Should	None
Class 3B	93%	7%	-
Class 4	100%	-	-

A.10 Alignment Eyewear

Section 4.4.4.2.5 (Class 3B or Class 4) - For all routine laser operations and for most laser alignment procedures, the LPE used *shall* provide full protection against a possible direct beam or specular reflection exposure. Use of alignment eyewear *shall* only be for specific alignment procedures with visible laser beams that have been appropriately evaluated and authorized. Alignment eyewear by definition involves the use of visible laser light. The LSO *shall* approve the selection, use, and appropriate OD for all alignment tasks. The LSO *shall* calculate OD values for both point source intrabeam and point source diffused (non-specular) viewing. If point source diffused OD values are employed in LPE selection by the LSO, notification to the end-user *shall* indicate that the wearer is not protected against a point source intrabeam exposure as its MPE values will be exceeded. For LPE alignment viewing, the LSO *shall* recommend LPE product(s) for alignment that meet the minimum OD requirement for viewing an ideal, point-source, diffuse reflection at a distance of 20 cm.

Survey Results: Alignment eyewear - has reduced attenuation from full protection and can be approved by the LSO for visible laser use. Requirements:

	Can always use with visible lasers	Can only use with special approval when full protection eyewear is not practical	Not allowed	No requirement
Class 3B	13%	53%	7%	27%
Class 4	7%	53%	13%	27%

A.11 Master Key/Switch

Section 4.4.2.2 Key Control (Class 3B or Class 4) - Class 3B or Class 4 lasers or laser systems *should* be provided with a master switch. This master switch *shall* effect beam termination and/or system shutoff and *shall* be operated by a key or by a coded access (such as a computer code). As an alternative, the master switch can be designed to allow system activation using a momentary switch action (or alternative) that initiates system operation with the option that the key (or alternative) can be removed after operation commences. In this mode, if the system ceases to operate, the key switch (or alternative) must again be used to restart the laser or laser system. A single master switch on a main control unit *shall* be acceptable for multiple laser installations where the operational controls have been integrated. All energy sources associated with Class 3B or Class 4 lasers or laser systems *shall* be designed to permit lockout/tagout procedures required by the Occupational Safety and Health Administration (OSHA) of the U.S. Department of Labor (see Section 10).

Survey Results: Master Key or Master Switch - will disable the laser(s) or laser system(s) when set to OFF position or removed, and must be used to restart the system. Requirements:

	Shall be provided and be removable	Shall be provided but does not have to be removable	Should be provided and be removable	Should be provided but does not have to be removable	No requirement
Class 3B	33%	7%	20%	27%	13%
Class 4	60%	20%	7%	7%	7%

A.12 Cover Interlock for a Class 1 Enclosure or Protective Housing

Section 4.4.2.1.3 Interlocks on Removable Protective Housings (All Classes with Embedded Class 3B or Class 4) - Protective housings that enclose Class 3B or Class 4 lasers or laser systems *shall* be provided with an interlock system that is activated when the protective housing is opened or removed during operations and maintenance. The interlock or interlock system *shall* be designed to prevent access to laser radiation above the applicable MPE. The interlock may, for example, be electrically or mechanically interfaced to a shutter that interrupts the beam when the protective housing is opened or removed (see Section 7.2.1 for electrical hazards). Fail-safe or redundant interlocks *shall* be provided for any portion of the protective housing that, by design, can be removed or displaced during operation and maintenance, and thereby allow access to Class 3B or Class 4 laser radiation.

Section 4.4.2.1.4 Service Access Panels (All Classes) - Portions of the protective housing that are only intended to be removed from any laser or laser system by service personnel, which then permit direct access to laser radiation associated with a Class B or Class 4 or laser system, *shall* either: a) Be interlocked (fail-safe interlock not required), or b) Require a tool for removal and *shall* have an appropriate warning label (see Section 4.6.6) on the panel. If the interlock can be bypassed or defeated, a warning label with the appropriate indications *shall* be located on the protective housing near the interlock (see Section 4.6.1.3). The interlock design *shall* not permit the service access panel to be replaced with the interlock remaining bypassed or defeated.

Survey Results: Not part of survey.

A.13 Beam Stop/Attenuator

This requirement was removed from the (2014) revision. The 2007 revision had requirement as a “should” for Class 3B and a “shall” for Class 4.

Survey Results: Beam stop/attenuator device - is capable of preventing access to laser radiation above the MPE when the laser or laser system output is not required. Requirements:

	Shall	Should	None
Class 3B	40%	33%	27%
Class 4	67%	20%	13%

Appendix B 2016 DOE LSTG Benchmark Survey

This section states the result of a survey distributed to the LSTG members based on the control and rationale of each control item in this document. LSTG members were asked whether they agreed or disagreed with the requirement and rationale statements, and to provide a comment if they disagreed. Out of the twenty possible LSTG member Labs, there were sixteen survey responses from fourteen Labs. Where there was a disagreement and a comment was made, a response to the comment is included. Overall there was excellent agreement on the recommended policy requirement statements*:

- 5 controls statements had unanimous agreement from the 14 Labs
- 5 controls statements had 13 Labs agreeing and 1 disagreeing
- 2 controls statements had 12 Labs agreeing and 2 disagreeing
- 1 controls statement had 10 Labs agreeing and 4 disagreeing

*When two responses came from one Lab, the response from the LSO took precedence.

The first question concerns the types of laser operations performed at a respondent's facility.

Research Laser Labs (with associated Principal Investigators or Program Managers)	100%
User Facility (provided for non-employee research and investigations)	51.74%
Industrial Laser (primarily operated as Class 1 laser systems)	64.29%
Other	0.00%

The remainder of the survey pertained to the control items described in this document.

B.1 LCA Warning Device (Class 3B or Class 4)

One Lab disagreed with the requirement statement and two comments were made:

- "The interior LCA Warning device must be easily viewable to persons in the LCA."*
- "I agree with the "shall" for Class 4, but for Class 3B I align with ANSI-it should be a "should" statement."*

Response to comments:

- The group felt that there are situations where it may not be possible to have the LCA warning device(s) visible from every point in the LCA, thus this part of the requirement is kept as "should".
- Keeping the LCA Warning device requirement a "shall" for both Class 3B and Class 4 LCAs was also determined as best because Class 3B laser operation requires laser eyewear protection. Alternative controls may also be implemented in some cases, for example for a low power cw visible Class 3B laser. Alternative controls might include no unattended operation, or an administrative warning sign or warning light.

There was 100% agreement on rationale given for the requirement.

B.2 Emergency Stop (OFF) Device (Class 3B or Class 4 LCA)

One Lab disagreed with the requirement statement and a comment was made:

- i. *“While I think the emergency stop (ES) devices are a good idea, and we can require that going forward with for our new systems, this requirement would have significant impact to research program budgets to implement for our existing systems since many of them do not have ES devices. We don't have program funds to pay for this significant change which would run in the 10's of thousands if not more for the Lab as a whole. However, we would support the requirement if there was a strong rationale or strong value in doing so, but I'm not convinced that is the case for us.”*

Two Labs disagreed with the rationale given:

- i. *“I don't think so. As stated in Z136.1-2014, the "intended" purpose of the e-stop button is to deactivate the laser or reduce the output to levels at or below the applicable MPE, potentially very different. An e-stop which did the latter may not shut off the laser. In my mind, an e-stop cuts power to the laser, not just diminishes the output.”*
- ii. *“I don't necessarily agree with the rationale because: 1) 90% of our systems are Class 1 systems so emergency/rescue personnel would not be exposed to laser energy above 3R levels if they entered a lab 2) for the open-beam Class 3B or 4 systems, we require the systems have door interlocks that would activate a shutter or shutdown the laser power so emergency personnel would not be exposed above 3R levels. We require those interlock be routinely inspected so they should be functional in the event of an emergency. 3) I don't think our emergency personnel will enter a laser lab when the "laser in use" lights are activated unless we provide them with proper laser eyewear and ensure them it is safe to enter the space.”*

Response to comments:

- The group felt that the requirement statement was stronger than that given in both the ANSI Z136.1-2014 and the Z136.8-2012 and the respondent's comment was asking to go too far. Most laser laboratories do not connect their low-powered alignment lasers to the Emergency Stop (OFF) Device.
- For Class 1 operation, Emergency Stop capability would not be required.
- Class 3B and Class 4 laser labs are often locked and capability for safe emergency entry needs to be provided.
- Alternate controls can be considered for some situations where emergency stop is not practical, for example for a low power cw Class 3B visible laser.
- Emergency stop devices are not very expensive and can be interfaced with a laser's remote interlock input.

B.3 Remote Interlock Connector (Class 3B or Class 4)

There was 100% agreement on the requirement statement given.

There was 100% agreement on rationale given for the requirement.

B.4 Laser Safety Officer (LSO) Training

Two Labs disagreed with the requirement statement and two comments were made:

- i. *“Not exactly. LSOs should certainly be trained in some fashion LSO course offered by a credentialed group. I think certification of LSOs with the BLS is a great thing but I get a little nervous about the word **shall**. Very often at our facility, **shoulds** become **shalls** and with budget shortfall we have enough challenges trying to maintain other mandatory certifications that we may have.”*
- ii. *“Participation in meetings **should** not be a requirement. I don't even know if my organization would support attendance to all the meetings.”*

Response to comments:

- A change was made to the requirement statement to require participation as a member rather than to require participation in all meetings, *“The LSO **shall** participate as a member of the DOE EFCOG Laser Safety Task Group (LSTG) and **should** obtain LSO certification with the Board of Laser Safety.”* Concerning BLS participation, the group felt that since there is a credentialing body for LSOs we should not ignore certification. The requirement is kept as *“**should**”*.
- The group did not see participating and attending meeting to be over-burdensome. In a two year cycle there are five teleconferences and one face-to-face meeting at the Workshop. A member should be able to make at least most of the quarterly teleconferences.

Two Labs disagreed with the rationale given and three comments were made:

- i. *“I don't think a DOE LSO is automatically a member of the LSTG. I thought they had to opt in.”*
- ii. *“Rational given directly contradicts requirement statement. Minimum training listed in the rationale should match the minimum required LSO training - at the 5-day preparatory course level, not the "attends every meeting" level. “*
- iii. *“I agree in principle, but it is hard to implement at NNSS. I'm a CLSO, but most of my deputy LSOs are non-degree technicians.”*

Response to comments:

- The rationale was changed to, *“A DOE LSO needs to join the LSTG and is invited to participate in the meetings and workshops in order to stay current with laser safety in the DOE complex.”*
- The note on the 5-day training for an LSO was an informational note. The requirement does not dictate what the specific training should be.
- A definition for LSO was added, *“For the purpose of this document the LSO is the site-wide LSO with responsibility for the laser safety program at the site.”*

B.5 Standard Operating Procedures (SOPs) Requirements

There was 100% agreement on the requirement statement given.

There was 100% agreement on rationale given for the requirement.

B.6 Skin PPE Requirements

There was 100% agreement on the requirement statement given.

There was 100% agreement on rationale given for the requirement.

B.7 Skin Exams (UV)

The requirement statement in 2.7 was updated following the survey to take into account input from the EFCOG Occupational Medicine Task Group. They advised against a new requirement to provide a screening skin exam, that there was only a need to do an exam if there were exposure symptoms. The updated requirement statement takes into account 3 factors:

- i. Occ Med input,
- ii. Z136.1-2014 only gives a recommendation for a skin exam in an informational appendix, and
- iii. the 2014 survey result given in Appendix A.7 indicated that 80% of the Labs did not have a periodic skin exam requirement.

The requirement was updated to put the onus on the worker to request a skin exam if they experience UV exposure symptoms or have a concern about exceeding the UV MPE exposure limit.

The requirement statement for the survey was “Periodic skin exams should be given to personnel working with UV lasers who are at risk for exposure above the MPE, in particular to those who also have a history of photosensitivity.”

One Lab disagreed with the requirement statement, but did not leave a comment.

One Lab disagreed with the rationale but agreed in their comment:

- i. *“Agree with the rationale, but may not be applicable at NNSS.”*

B.8 Medical Baseline Eye Exam

Two Labs disagreed with the requirement statement and three comments were given:

- i. *“Baseline eye exam with photo of the retina should remain a “shall” requirement. It is the only way to document changes in the retina, possibly due to exposure, pre and post operations.”*
- ii. *“We require pre-placement baseline exams prior to using class 3B/4 lasers.”*
- iii. *“We are moving to eliminate the eye exam requirement.”*

Response to comments:

- The group felt that the “*shall*” requirement was too stringent (thus keeping recommendation as “*should*”) as the ANSI Z136.1-2014 no longer requires it, stating only that it “*should be considered*” for personnel exposed to Class 3B and Class 4 laser radiation. The photo of the retina has not been required going all the way back to at least the 1986 revision of ANSI Z136.1.

Three Labs disagreed with the rationale given:

- i. A "should" requirement becomes an automatic cost cutting measure since it is "not required." The baseline eye exam should become a "shall" prior to any operations with Class 3b or 4 Lasers.
- ii. The medical baseline eye examination has very specific purpose which is not to provide "fitness for duty". This can be accomplished by the new employee entrance health examination which most of the Labs recommend and practice already. It is useful, but does not have to be a part of the laser program.
- iii. Do not see a benefit

Response to comments:

- The group agreed that the requirement remain a "should" rather than "shall". As each Lab is run by individual contract, fitness for duty can be accomplished in different ways, i.e. health exam, eye exam, etc.
- Benefits to performing the eye exam are given in the rationale.

B.9 Full Protection Laser Eyewear

There was 100% agreement on the requirement statement given.

There was 100% agreement on rationale given for the requirement.

B.10 Alignment Eyewear

There was 100% agreement on the requirement statement given. One comment was given:

- i. We do not permit the use of alignment eyewear.

There was 100% agreement on rationale given for the requirement.

B.11 Master Key/Switch

Four Labs disagreed with the requirement statement and four comments were given:

- i. "Overly restrictive."
- ii. "I agree with ANSI and the "should" statement."
- iii. "We have several unique situations where a master key may not be feasible."
- iv. There is value in having master keys available for laser systems as they provide capabilities for administratively locking out a system when needed (e.g. following a laser incident, or if the safety systems are not functional and need to be repaired). However, beyond that function, our site is a secure, controlled site and we have not had any issues in 30 years that would have warranted the need to have master key control. Not all of our systems have this capability, so we would need to use research program funds if we made this requirement. I would prefer to see this as a "should" requirement (i.e. in alignment with the ANSI Z136.1 requirement)."

Response to comments:

- The group felt that all commercially sold Class 3B and Class 4 laser must have a key-controlled power supply, so the device is already in place for these. For most lab-built lasers it is generally not very expensive to add a key control. For other lab-built lasers, where it may not be practical to add a key control, alternative controls can be put in place.

Three Labs disagreed with the rationale given for the requirement, and one statement was given:

- "The way it is written only a single master key can disable the laser system. I think it should be expended to include what other alternatives can serve the same purpose."*

Response to comments:

- The group added, "An LCA may have a single Master Key or multiple Master Keys" to the Informational Note.

B.12 Cover Interlock for a Class 1 Enclosure or Protective Housing

One Lab disagreed with the requirement statement:

- "More or less though I would change the wording in item "ii" to read "removed" rather than "removable"."*

Response to comment:

- The requirement statement was changed to, "If only removed during infrequent service tasks **shall** either:..."

One Lab disagreed with the rationale given for the requirement, but no comment was given.

B.13 Beam Stop/Attenuator

One Lab disagreed with the requirement statement:

- "**should**" will decrease the level of safety from "**shall**" I do not understand the drive for removing the requirement from the latest version."*

Response to comment:

- The group felt that the "should" requirement is stronger than ANSI Z136.1-2014 where the requirement was removed.

One Lab disagreed with the rationale given for the requirement:

- "**should**" will decrease the level of safety from "**shall**" I do not understand the drive for removing the requirement from the latest version."*

Response to comment:

- The group felt that the rationale given is an important best practice, to be used for example when warming up a laser system is required. Options for how to implement the beam stop or attenuator are suggested in the Informational Note.