



INTERNATIONAL LASER  
DISPLAY ASSOCIATION



# Category A Laser Show Standard

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# 1. ILDA Category A Laser Show Standard: Introduction

This ILDA Standard defines a "Category A Laser Show" or display as used in the entertainment, advertising, and artistic composition fields. Such laser shows are accepted popular media in entertainment and the arts.

## 1.1. Nomenclature

The shorter name "Cat A" is alternative nomenclature to "Category A." It will be used in this document, since we expect it will be used in the laser show industry. This is similar to how Ethernet cable is more commonly identified as "Cat 5", "Cat 6" etc. instead of "Category 5" or "Category 6".

## 1.2. Application

This standard applies to conventional laser beam shows that use a directly emitted laser beam which then may be steered by mirrors (galvos) or diffracted by various materials. The laser light may create mid-air atmospheric effects and/or relatively simple vector graphics and animations.

This standard does NOT apply to laser-derived lighting sources that begin with laser light, then make it incoherent and otherwise modify it inside a housing so that the resulting emitted light is similar to conventional non-laser light sources. These include Laser Illuminated Projectors, Laser Pumped Lighting, and Laser Illuminated Lighting Instruments.

## 1.3. Background

The ILDA Cat A Laser Show Standard sets forth easy-to-follow requirements that have been proven to provide basic laser safety for a light show.<sup>1</sup> These requirements are also straightforward for a regulator or inspector to confirm.

The Standard makes laser light show safety as simple as reasonably possible. For example, it does not allow human exposure to laser light such as audience scanning. This, along with Continuous Monitoring of the laser show and a limitation of 6 watts on power, provides significant safety.

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<sup>1</sup> See the Appendix "Record of laser light show safety" for more information.

An ILDA Cat A Laser Show incorporates standard conditions of a U.S. Food and Drug Administration (FDA) variance<sup>2</sup>. Such a show should not have a problem in obtaining an FDA variance so that it can be U.S.-legal as well as safe.

In fact, in some cases it goes beyond FDA conditions. For example, bounce mirrors are not permitted and there are more detailed requirements for training.

ILDA Cat A Laser Show requirements are based strictly on the hazard classification of the projector; e.g., that it is a Class 3B or 4 laser projector. By doing so, this approach does not require calculation of the Maximum Permissible Exposure (MPE), the Accessible Emission Limit (AEL), the Nominal Ocular Hazard Distance (NOHD), or the Nominal Hazard Zone (NHZ).

#### 1.4. Generally recognized as safe

An ILDA Cat A Laser Show is generally recognized by ILDA as safe under the conditions of its intended use.

The chance of injury -- defined as a "hazardous effect" or an "adverse biological change" to any person -- is considered by ILDA to be vanishingly small, as long as the requirements of this Standard are met.

*Note: This does not mean that Class 4 lasers which are less than 6 W are safe. **Any Class 3B or 4 laser beam is inherently hazardous and needs to be treated with care.** This does mean that if such a laser is used **along with the other required conditions** of an ILDA Cat A Laser Show, the laser show is generally recognized by ILDA as safe.*

#### 1.5. ILDA recognition of ILDA Cat A Laser Shows

The International Laser Display Association will not object to laser shows that meet the requirements in this Standard. These requirements are based on generally accepted government regulations, safety principles, and/or safety standards from groups such as the American National Standards Institute (ANSI) and the International Electrotechnical Commission (IEC).

A laser show that deviates from these requirements is, by definition, not an ILDA Cat A Laser Show. It should follow requirements of other standards such as ANSI Z136 and IEC 60825 plus any requirements set by government and/or an Authority Having Jurisdiction.

*Regulatory Note: An ILDA Cat A Laser Show in general follows the standard conditions listed in a U.S. FDA laser light show variance. However, to be legal in the U.S. at the federal level, any laser light show, display or device that is introduced into commerce and that uses Class 3B or 4 lasers must apply for a variance and must receive FDA approval before introducing the show into commerce (e.g., before rehearsing and performing the show).*

*In any country, there may be not only national regulations, there may also be state/provincial, local and*

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<sup>2</sup> As embodied in FDA Form 3147, "Application for a variance from 21 CFR 1040.11(c) for a laser light show, display or device."

*city regulations covering laser shows. To be legal, a show must meet all applicable regulatory requirements for its location..*

*Note that regardless of a show's legal regulatory status, ILDA will not object to the show if it meets or exceeds the ILDA Cat A Laser Show requirements.*

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## 2. Summary of Requirements and Recommendations

### 2.1. Requirements vs. recommendations

In this Standard, "**shall**" refers to a requirement which must be met. "**Should**" refers to a suggested recommendation which is not an absolute requirement. Because these terms are so important, they have been color-coded in **green** ("a must") and **orange** ("a recommendation").

The terms "may" or "can" refer to actions which are optional. They are of less importance than a "**should**" recommendation, which is also optional.

The sections of this Standard with **blue** section headers are required to make an ILDA Cat A Laser Show. The sections in **brown** are Appendices which are informative only (not part of the Cat A requirements).

### 2.2. Summary of major points

The following is a summary of the major requirements and recommendations in this Standard. They apply to the use of Class 3B and 4 lasers emitting visible beams (400-700 nm) at laser shows and displays.

- 6 watts maximum power from any one laser beam
- Continuous wave lasers only; no pulsed lasers such as metal vapor or pulsed Nd:YAG
- No unterminated beams.
- All beam termination points must be visible to the Laser Operator, assisted if necessary by Laser Spotters.
- Use FDA-certified laser projectors in the U.S.
- No human exposure to Class 3B or 4 laser light
- Continuous Monitoring of all beam paths, locations and termination points during laser emission by a trained Laser Operator, assisted if necessary by Laser Spotters so there are no unmonitored paths/locations/termination points.
- The Laser Operator must have an e-stop or equivalent method to immediately stop emission in case of an actual or imminent laser safety hazard
- Secure mounting of laser projectors, and masking of laser emissions to restrict them to intended, safe areas
- Prevent damage to materials
- Anticipate problems in advance of the show, and plan for mitigation procedures
- Keep a log of all laser usage, and any problems/issues that may arise
- Formal classroom-type training is required for Laser Safety Officers. Informal training by LSOs or other qualified persons is required for Laser Operators. Training and/or instruction is required for Laser Spotters and Laser Personnel.

- The person(s) responsible for the laser show's safe design and operation shall have LSO formal training, which includes taking an in-person or live online classroom-type course, and passing a test.

A fuller list of all requirements is in the Appendix "Checklist" at the end of this document. The checklist is useful for persons wishing to review or summarize the full Standard.

*Note: Although the Standard may seem long, the part covering actual laser show operations (Section 3) is only about 12 pages. Numerous examples, explanatory notes, and appendices have been added to help persons who are new to laser shows, to standards, or both. If the main body becomes overwhelming, refer to the Appendix "Checklist" at the end of this document for an overview.*

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## 3. Laser Show Operations

### 3.1. Only visible lasers

Laser radiation emissions **shall** be within the visible wavelength range of 400 nm to 700 nm.

### 3.2. Only continuous wave lasers

Only continuous wave (CW) lasers **shall** be used.

Specifically, lasers emitting light in pulses such as pulsed Nd:YAG and metal vapor lasers **shall not** be used. This applies even to lasers with very high pulse repetition rates such as 80,000 Hz.

### 3.3. Use of Class 1, 2 and 3R lasers

If Class 1, 2 or 3R lasers are used in the show, they **shall** be used in a manner consistent with the manufacturer's instructions and warning.

If Class 3R lasers are used in the show, they **should not** be intentionally aimed at a person's eyes or face. If Class 3R lasers are left operating unattended, they **should** be used only in an area where the public is not intended to be.

**IMPORTANT: The remainder of this Standard applies only to light and beams from Class 3B and 4 lasers<sup>3</sup>, except where otherwise noted.**

### 3.4. Maximum power: 6 watts

The maximum power emitted by a single laser beam from an aperture of the laser or laser show projector **shall not** exceed 6 watts. The power is determined by valid measurement or reputable manufacturer information. If any single beam emitted during the show is or could be over 6 watts, then the entire show does not qualify as an ILDA Cat A Laser Show.

It is not permitted to use lasers of more than 6 watts and turn down the power to be less than 6 watts.

It is permitted to use elements such as filters, beam splitters or diffraction gratings to reduce the power of a laser beam greater than 6 watts, so that the emitted beam(s) is(are) less than 6 watts; if such elements are 1) fixed in place and 2) cannot be removed or bypassed during a show without the use of tools.

*Note: As noted earlier, this does not mean that Class 4 lasers which are less than 6 W are safe. **Any Class 3B or 4 laser beam is inherently hazardous and needs to be treated with care.** However, this does mean that*

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<sup>3</sup> Class 3B lasers emitting visible light are between 5 mW and 499.9 mW. Class 4 lasers are those 500 mW and above.

if such a laser is used **along with the other required conditions** of an ILDA Cat A Laser Show, the laser show is generally recognized by ILDA as safe.

### 3.5. Use only certified/approved lasers and projectors

#### 3.5.1. United States

For an ILDA Cat A Laser Show performed in the United States, all laser equipment (products, systems, and projectors) used in the show **shall** be certified to FDA. This means the laser equipment manufacturer must have an approved variance, currently in effect, from FDA to deviate from 21 CFR 1040.11(c). Specifically, any laser projection systems which have been certified and reported by their manufacturer to comply with the applicable parts of 21 CFR 1040.10 except for deviations allowed under an approved laser light show variance or FDA Guidance Documents (Laser Notices). Laser equipment **shall** have a manufacturer's certification label that contains their variance number, and the date their variance went into effect.

*Note: This requires ILDA Cat A Laser Shows in the U.S. to use U.S. legal laser light show projectors and equipment; e.g., ones which have been certified to FDA.*

#### 3.5.2. Outside the U.S.

For an ILDA Cat A Laser Show in a jurisdiction outside the U.S., all laser products, systems, and projectors used in the show **shall** be certified, inspected or otherwise approved for use under the laws and regulations of the jurisdiction. If unsure of local regulations, refer to the International Electrotechnical Commission standard for laser products, IEC 60825-1 (current edition).

### 3.6. Allowed effects

Only the following effects may be used in an ILDA Cat A Laser Show:

- Projections onto screens and surfaces. This can be front or rear projection.
- Beams through the air
- Beams through light-scattering enhancement media such as haze, smoke or fog<sup>4</sup> that are added to the air
- Multiple reflection/diffraction effects created at the laser projector
- Terminated beams

The following are some examples of effects that may NOT be used in an ILDA Cat A Laser Show:

- Audience scanning
- Illumination of persons with any Class 3B or 4 laser
- Unterminated beams (e.g., going to an unknown location or into airspace)
- Bounce mirrors and bounce holographic gratings

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<sup>4</sup> Some methods of creating haze, smoke and fog may be health hazards. Consult other sources to determine safe methods of introducing atmospheric light-scattering media.

### 3.7. Example venues

Examples of venues where an ILDA Cat A Laser Show could take place:

- Planetariums
- Theaters and cinemas
- Store displays
- Trade shows and exhibitions
- Discotheques and night club and music festivals
- Pavilions
- Auditoriums
- Hotel meeting rooms (larger ones, not small conference rooms), ballrooms and convention halls
- Outdoor enclosed areas where all beams are terminated and crewed aircraft cannot safely fly or land

Examples of venues where an ILDA Cat A Laser Show might not be appropriate or effective:

- ~~Private homes~~. The rooms may be too small for the 3m/2.5m separation distances, and 6 W of beam power might be too high for such a relatively small space.
- ~~Indoor or outdoor arenas and outdoor concert locations~~. Greater than 6 watts may be needed to "punch through" the long distances.

This Standard prohibits outdoor shows with unterminated beams, or with beams that go into navigable airspace. Such shows can of course be done, but they would not be an ILDA Cat A Laser Show.

### 3.8. Beam termination

All laser beams **shall** be terminated (ended) on a diffuse, non-reflecting surface. The surface **shall not** be damaged by the laser beam.

All beam paths and termination points **shall** be in locations controlled by the facility/venue and/or the event operator. All beam paths and termination points **shall** be visible by the Laser Operator who is assisted, if necessary, by one or more Laser Spotters.

#### 3.8.1. Terminated beams outdoors

All beam paths outdoors **shall** be in non-navigable airspace; that is, airspace where crewed aircraft including helicopters would not be able to safely fly or land even in case of an emergency.

*Note: An acceptable outdoor location would be an enclosed patio or courtyard where it would be impossible for a helicopter to safely fly or land. An unacceptable outdoor location would be to aim beams from one building to another across a street, if police or rescue helicopters could fly up the street and through the beams.*

*If unsure about whether beam paths could be accessed by crewed aircraft, for a Cat A show do not use the beams. (It is possible to consult with the appropriate governmental aviation/airspace*

authority such as the U.S. FAA, but such complexity goes beyond the simple requirements of the ILDA Cat A Laser Show Standard.)

### 3.9. Beam locations - All persons

The only laser light from Class 3B and 4 lasers allowed on any person or in accessible uncontrolled areas is diffuse reflections produced by 1) the atmosphere, 2) added atmospheric scattering media such as haze or fog, and 3) reflections off target screens.

*Note: This means that "audience scanning", where beams and laser light are deliberately aimed onto the General Public, is specifically prohibited for an ILDA Cat A Laser Show.*

*In addition, this Standard also prohibits beams and laser light from being deliberately aimed onto Laser Personnel.*

### 3.10. Beam locations and distances - General Public

The following applies to beam locations for the General Public. This includes audiences, workers not employed by the Employer (this term is defined later in this Standard), and any other persons in the laser show area who cannot be expected to know about laser hazards and/or who cannot be expected to reliably follow instructions to avoid such hazards.

#### 3.10.1. Separation distance

Beams **shall** be at least 3.0 meters (9' 10") above any surface upon which the General Public may be reasonably expected to stand, and **shall** be at least 2.5 meters (8' 2") below or in lateral separation from any place where the General Public is permitted to be.

*Note: "Reasonably expected" may depend on the venue and event type. In a concert hall with classical music, persons are not reasonably expected to stand on chairs. At a music festival, persons may be standing on chairs or structures. So the actual laser minimum height above the floor or ground may need to be higher at a music festival than in a concert hall.*

#### 3.10.2. Beam termination on a balcony

Beams **shall not** be aimed towards or terminated on a balcony or other structure within the scan field of a laser projector, if there is less than 2.5 meters separation between where the General Public is permitted to be and the closest beam.

For example, if the public can reach over a balcony, there must be at least 2.5 meters as measured from the closest location where a body part is blocked by the balcony (the armpit if reaching an arm over), to the closest beam location.

*Note: While it is technically possible to use hardware or software masks to prevent beams from reaching specified areas (such as a balcony) inside a scan field, this requires specialized knowledge, care, and procedures beyond the scope of the ILDA Cat A Laser Show Standard.*

### 3.11. Beam locations and distances - Laser Personnel

The following applies to Laser Personnel. These are persons who have been made aware of the laser's hazards AND who can reasonably be expected to follow instructions to avoid such hazards. These persons include Laser Operators, employees of the Employer (defined later), and stagehands and performers who have been briefed and who will follow safety instructions.

*Note: For purposes of this Standard, a person is either classified as being in the General Public or is Laser Personnel. If unsure, classify them as General Public.*

#### 3.11.1. No laser light on any Laser Personnel

It may be necessary for Laser Personnel such as the Laser Operator or performers to be closer to laser beams than the 3 meter vertical/2.5 meter lateral separation distance specified above.

In such cases, laser light may be closer to Laser Personnel if they have been briefed on the beam and light locations and if they can reasonably be expected to avoid such locations.

Laser light **shall not** be on Laser Personnel, whether on bare skin, clothing or other wearable protection. Further, laser light **shall not** be close enough to any Laser Personnel so that in the course of their reasonably expected movements any part of their body (including clothing) may be exposed to the laser light; for example, if a performer turns around to face the rear of the stage or a stagehand needs to walk near an open beam.

*Note: Beams in an ILDA Cat A Laser Show cannot be on a person even if they have, for example, laser eye protection. This can be done in non-Cat A shows if proper protection is used. But for Cat A, it is easiest for safety and enforcement to simply prohibit beams from being on any person, whether General Public or Laser Personnel.*

### 3.12. No unsafe reflected beams

Beams **shall not** be reflected off mirrors or other specular reflective surfaces (examples: mirrored walls, chandeliers, lighting instrument lenses) which are already in the facility or venue, if such reflections go into accessible areas and violate the 3 meter vertical/2.5 meter lateral separation distance.

### 3.13. No added bounce or diffraction mirrors

No new mirrors, specular reflective surfaces, or reflective or transmissive surfaces (example: diffraction gratings), may be added in the facility or venue for purposes of bouncing or diffracting the beam.

*Note: A small misalignment at the laser projector may mean the beam misses its target by many inches or feet. While it is technically possible to aim lasers at bounce mirrors, this requires specialized knowledge, care, and procedures beyond the scope of the ILDA Cat A Laser Show. This is why bounce mirrors are prohibited for Cat A shows.*

### **3.14. Secure mounting of lasers and associated devices**

The laser and all other components whose positioning changes or affects the beam location, power, or divergence **shall** be securely mounted or fixed in place to prevent unintended movement or misalignment.

In addition, for an ILDA Cat A Laser Show, the laser and other components referenced above **shall not** be on a structure that is moved during the show, even if laser emission is off during the structure's movement.

Laser light may be aimed towards a movable structure or target under two conditions only:

- 1) The light can be fully contained on the structure or target, no matter where it is positioned within its capable range of motion, or
- 2) If the light misses the structure or target, it is terminated in a safe area and does not violate any beam location and distance requirements of this Standard (for example, the light remains at least 3m vertically or 2.5m laterally from the General Public).

### **3.15. Setup and alignment power levels**

For projectors that have analog (variable) beam intensity, setup and alignment **shall** be done at the lowest brightness level necessary to see the beam locations, until their final position is fixed.

For projectors that have TTL (only on or off) beam intensity, additional measures **shall** be taken to prevent inadvertent exposure while setup and alignment are being done, since the beams will be projected at full power.

### **3.16. Access restriction and/or signage**

Human accessible areas which may contain light from Class 3B or 4 lasers **shall** be clearly identified by 1) restricting access through physical means such as barriers, guards, pressure switches, photo cells, etc. (preferred) and/or 2) by the posting of warning signs. These requirements apply to temporary areas such as during setup and alignment procedures, as well as to final or permanent areas.

*Note: Avoid relying solely on signage to prevent access by the General Public. Signage is a reminder, but many people may not read or may actively ignore warning signs.*

*Signage intended for Laser Personnel has a greater chance of being followed, especially if Laser Personnel have been instructed to notice and heed the signs.*

### 3.17. No electromagnetic interference

Electronic controls and circuits **shall** be adequately shielded to prevent electromagnetic sources (e.g., walkie-talkies, headset radios, wireless microphones, cellular telephones, etc.) in the vicinity of the projector, its active projection heads, and control system(s) from causing the laser emissions to be misdirected from their intended target area.

### 3.18. Beam masking to keep beams to known locations

Beam masking **shall** be used as needed to prevent laser light from going into areas prohibited by this standard. Such masking can be done by physical means using opaque, laser-safe material, or by software control of the beam intensity based on its location (a "beam attenuation map").

All masking and projection zones **shall** be tested and validated prior to each show to ensure beams cannot go beyond the set limits. One or more specific test patterns **should** be used for this purpose.

#### 3.18.1. Physical masking

If done by physical means, the laser projector and the physical masking of the laser output aperture **shall** be sufficiently rigid with respect to each other and sufficiently far from the aperture to restrict the beam to the intended safe areas.

#### 3.18.2. Software masking

If done by software control, the mask **shall** be tested prior to each show to ensure beams cannot go beyond the software-set limits. One or more specific test patterns **should** be used for this purpose.

*Note: Masking is best understood as one element helping to keep a show safe. It is useful for blocking out large areas such as an audience. If a mask fails such that some laser light is on persons or is in an accessible area, the backup is the Continuous Monitoring of the Laser Operator. They would notice the unsafe laser light, and would quickly stop laser emission until the mask can be properly adjusted.*

*For more detailed information, see the discussion in the Appendix about beam masking limitations.*

### 3.19. Prevent uncontrolled damage to materials

No laser beam **shall** cause materials damage which is potentially hazardous to humans, including creating smoke or starting a fire. No laser beam **should** cause damage to materials even if there is no human hazard created.

*Note: Higher power Class 3B beams, and Class 4 beams, can heat materials. Depending on the material color and susceptibility to damage, this can cause materials to smolder, melt, burn or otherwise be damaged.*

*Note: Video camera sensors, projector imaging elements and some LED lighting instruments are susceptible to being damaged by laser light. Due to the lens concentrating incoming laser light, this damage can happen at irradiance levels below that which would cause harm to other materials or the human eye. The laser show*

*producer should take reasonable precautions to avoid damage to cameras, projectors and lighting instruments -- especially expensive professional ones. However, if such damage does occur, it is not considered to violate the requirements of an ILDA Cat A Laser Show, which is concerned with human safety.*

### **3.20. Maintain laser safety at all times**

Laser safety **shall** be maintained at all times during all phases of the show production, including during setup, alignment, rehearsal, performance and tear down.

Persons in the area of beams, such as during setup and alignment, **shall** be warned and notified prior to beam emission. If they are Laser Personnel, they **shall** be instructed in how to safely operate if they are closer than 3 meters vertically/2.5 meters laterally to a beam.

There **shall** be no General Public persons within 3 meters vertically/2.5 meters laterally to any laser light during any phase of the show production.

### **3.21. Designed or supervised by a Laser Safety Officer**

The Cat A laser show **shall** be designed, or the design **shall** be supervised, by a person with Laser Safety Officer training as described elsewhere in this Standard. The training **shall** include coverage of the requirements of the Cat A Standard.

*Note: LSOs who took a course prior to the adoption of the ILDA Category A Laser Show Standard, may take a refresher course to comply with the above provision. ILDA will allow a one-year grace period from the date of adoption of the Cat A Standard, during which passing an LSO training course is still required -- but not necessarily a course which covers the Cat A Standard.*

### **3.22. Trained, competent Laser Operator**

The laser show **shall** be under the direct and personal control of a trained, competent Laser Operator. All of the following conditions **shall** be met:

#### **3.22.1. Age: 17 or older**

The Laser Operator **shall** be 17 years of age or older.

#### **3.22.2. Under control of the Employer**

The Laser Operator **shall** be under control of the Employer (this term is defined later in the Standard), who **shall** be responsible for the training and conduct of the Laser Operator. While the Laser Operator does not have to be an employee, there **shall** be a financial or other relationship such that the Laser Operator will do as instructed by the Employer.

*Regulatory note: FDA requires the Laser Operator to be "an employee of the variance holder". FDA does not define what constitutes an employee relationship. An ILDA Cat A Laser Show does not require an employee relationship, but does require that the Laser Operator follow the Employer's instructions.*

### 3.22.3. Laser Operator training and instructions

The Employer or LSO **shall** provide training and instructions to the Laser Operator adequate to maintain laser safety throughout the scope of the Laser Operator's tasks. The Laser Operator **shall** be able to identify all reasonably foreseeable laser hazards, and **shall** know how to mitigate (reduce or remove) those hazards.

The Laser Operator **shall** take direction from the Employer and LSO in laser safety-related matters.

### 3.22.4. Authority and responsibility of the Laser Operator

The Employer **shall** give the Laser Operator the authority and responsibility to maintain laser safety despite pressures from other parties to operate or change the show to make it less safe.

This includes giving the Laser Operator the authority and responsibility to direct others in order to maintain laser safety; for example, by ordering persons away from prohibited areas.

The Employer is responsible if the Laser Operator does not maintain laser safety.

### 3.22.5. All beams can be seen

The Laser Operator **shall** be located where all beam paths can be directly and conveniently observed at all times during laser emission, or be in continuous contact via headset or similar means with one or more Laser Spotters such that the entire group of Operator plus Spotter(s) **shall** be able to directly observe all beam paths during laser emission.

*Note: "Directly and conveniently" means that the Laser Operator does not need to turn around or otherwise contort to see the entire beam path. If it is not possible to conveniently see the entire beam path of all beams, then it is required to use one or more Laser Spotters during laser emission, who are in continuous contact with the Laser Operator.*

### 3.22.6. Continuously Monitor the lasers

The Laser Operator **shall** have no duties during laser emission other than operating the lasers and Continuously Monitoring the laser emission for actual or imminent hazards. Such hazards include if the laser beams are close to humans, if the audience is unruly, or if there are changes to the laser targets (moving stage sets).

If operating the laser console or software interferes with the Laser Operator's duty to Continuously Monitor the laser emission, then one or more other persons **shall** be designated as Laser Spotters and **shall** Continuously Monitor the laser emission for imminent hazards. Additional discussion of the Laser Spotters' duties are later in this Standard.

*Note: Continuous Monitoring is vitally important. It is the "last resort" if other safety measures fail.*

*For example, if a beam is misaligned or someone climbs a truss into the beam path, Continuous Monitoring will notice. Even if a powerful beam goes into the audience, by Continuous Monitoring the Laser Operator or a Laser Spotter will notice and will stop the beam emission, thereby restricting the scope of any possible injuries.*

*A show without Continuous Monitoring is by definition not a safe show. It is so critical that it is a capitalized term in this Standard.*

### 3.22.7. Remote monitoring

Remote monitoring via video or similar means is permitted for relatively small, specific laser areas not directly visible to the Laser Operator. The video **shall** adequately display the extent of the laser emissions as well as the area and activities around the laser emissions. The monitor image **shall** be continuous, with no switching between different cameras. The monitor **shall** be placed so the Laser Operator or a Laser Spotter can glance at the image without a delay.

*Note: Normally, Laser Spotters should be used. An example of where remote monitoring is acceptable would be an all-day trade show where some projectors are on top of a booth, aimed at a wall, and are not visible from the laser console inside the booth. Video monitoring would allow a single Laser Operator to glance at the monitor to ensure the wall images are in the correct position, no one is climbing up through them, etc.*

### 3.22.8. Access to laser emission stop controls

The Laser Operator, during any laser emission, **shall** have immediate access at all times to controls that stop laser beam emission, such as an e-stop or software screen "off" or "stop" button.

If the sole means of stopping laser beam emission is a software button, the button **shall** be visible, accessible and operable at all times during laser emission. Prior to running the software program, and after exiting the program, the laser **shall not** emit light.

There may be multiple e-stops or software buttons, each controlling a separate laser or group of lasers. This way, if one laser or group of lasers creates a safety hazard, it can be shut down without affecting the rest of the lasers. If this is done, each e-stop **shall** be clearly marked, and the Laser Operator **shall** be aware and trained so that the correct e-stop is activated if necessary.

*Note: Such a partial shutdown also makes it more likely that a Laser Operator will press the e-stop. They know the "show will go on" with the rest of the lasers (those not presenting a hazard).*

### 3.22.9. Mitigate hazards or stop emission

If laser emission presents a hazard at any time, including during setup, alignment, rehearsal, performance, or tear down, the Laser Operator **shall** immediately mitigate the hazard or stop laser emission.

*Note: Other laser light may continue if it is not related to the unsafe conditions. This allows use of multiple e-stops or similar. If an unsafe condition arises in one area, one laser or set of lasers can be stopped while other, safe, lasers continue emitting in other areas.*

### 3.22.10. Stop all lasers in case of emergency

The Laser Operator **shall** immediately stop the emission of all laser light in case of an emergency at the venue such as, but not limited to, crowd disruption, panic, fire alarm, or a shooting.

### 3.22.11. Stop upon request of an authority

The Laser Operator **shall** immediately stop the emission of laser light upon the request of an Authority Having Jurisdiction<sup>5</sup> over the laser operation, such as a city or state radiation control officer, or (in some jurisdictions) a fire department official. For purposes of this Standard, an Authority Having Jurisdiction also includes venue owners and those in charge of an event at which the laser show is taking place.

*Note: This Standard does not allow for reducing the laser power. It only permits stopping the laser emission. This is because fewer decisions need to be made: Either keep the beam on, or turn it off. Also, it is easier for inspectors and others to determine compliance by observing the laser beam turning completely off.*

## 3.23. Do not change the show during performance

No new laser effects, or deviations from the planned laser operation, **shall** be introduced during the active show or display. Only those laser effects and operations agreed upon prior to the show **shall** be performed during the show.

If there are changes to be made, they **shall** be accomplished either prior to, or after the show.

Any new effects, or deviations from the planned laser operation, **shall** comply with the requirements for an ILDA Cat A Laser Show.

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<sup>5</sup> "Authority Having Jurisdiction" means a federal, state, provincial, local, or other regional department; or an individual such as a fire marshal, building official, electrical inspector, utility provider or other individual having statutory authority over a venue, event, gathering, etc. In this Standard, ILDA extends this term to include those having actual authority over a venue or event.

### 3.24. Anticipate problems, and plan for mitigation

The show **shall** be reviewed in advance for factors which may adversely affect safe laser operation. Contingency plans **shall** be made to address potentially adverse events, including those which may be considered unlikely to occur.

*Note: Most reported laser show incidents and accidents involving the general public have been due to events which could have been foreseen and planned for. Numerous examples are listed in the Appendix "Discussion of topics in this Standard," in the section on anticipating problems.*

### 3.25. Record-keeping log

A log **shall** be kept of the date and location of all laser emissions associated with an ILDA Cat A Laser Show, including setup, alignment, rehearsals, and performances. A record of the time, or approximate time ("late morning", "early evening"), of laser emission **shall** also be kept. Additional information on projectors, aiming locations, etc. **shall** also be kept in sufficient detail to confirm compliance with the requirements of this ILDA Cat A Laser Show Standard.

#### 3.25.1. Recording incidents and accidents

Incidents and accidents **shall** be recorded in the log:

- An **incident** is an event which potentially could have caused personal injury or property damage, but did not.
- An **accident** is an event which caused personal injury or property damage.

This logging requirement applies no matter who reports the incident or accident -- audience, crew, performer, etc. -- or even a person not at the show such as a medical professional. The log serves to record that there was a reported occurrence; it does not prove or disprove the validity or causality of the incident or accident.

#### 3.25.2. Log-keeping method

The log **shall** be kept in paper form and/or in electronic form. Either format is acceptable as long as the information is readable and is readily accessible at the laser show site upon the request of an Authority Having Jurisdiction over the laser operation.

#### 3.25.3. Length of record-keeping

Each record in the log **shall** be kept for at least one year from the date of laser emission stated in the record.

*Regulatory Note: An FDA laser light show variance requires information "in sufficient detail to confirm compliance with the regulations and this variance." Thus, FDA requires additional information about regulatory compliance which is not required by ILDA for a Cat A Laser Show.*

### 3.26. Video recording suggested

It is suggested, but not required, that each ILDA Cat A Laser Show **should** be recorded by video means. The video recording **should** be kept for at least one year from the date of the show.

The video **should** be made available upon request to any federal, state/provincial or local official with statutory authority over laser light shows. At the discretion of the video owner, the video may also be made available to any Authority Having Jurisdiction.

The video **should** be of sufficient resolution and quality to show all beam locations and termination points. If this cannot be done with a single camera, then multiple cameras **should** be used.

*Note: This would allow authorized persons to view previous laser shows, if they feel there might be an issue with the safety of how the show is performed. This also can put the laser show producer and Laser Operator on notice that all shows will be recorded, so safety measures need to be maintained even without an on-site inspector.*

### 3.27. Notice to authorities

The show **should** be done in compliance with all applicable notification, registration and certification requirements of the jurisdiction(s) where the show takes place.

*Note: This Standard covers the safe use of lasers in entertainment and display. If the ILDA Cat A Laser Show requirements are followed, ILDA considers the show to be generally recognized as safe.*

*It is not the intent of this Standard to require, as a safety measure, that the show must comply with any and all relevant laws. Such laws have their own requirements and penalties. They do not need further assistance from this Standard in order to apply legal requirements to laser show producers.*

*Regulatory Note: As previously described, to be legal in the U.S. at the federal level, any laser light show, display or device using Class 3B or 4 lasers must apply for a variance and receive FDA approval before introducing the show into commerce. FDA requires notice of laser shows through the Form 3147 variance procedure, as well as related submissions such as the Form 3640 laser light show report and the Form 3636 annual report requirement. Use these forms, reports and documents to make a federally-legal show in the U.S. In addition, some state/provincial, local and city authorities may require notice of laser shows, registration of the laser equipment, and/or certification of the laser operator.*

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## 4. Roles of Various Entities at Laser Shows

At a laser show, there are entities with many different roles. These can include the venue management, the band or performers hiring lasers, the general show production company, the production staff including stagecraft unions, the persons or companies providing the lasers, persons setting up and operating the lasers, and persons such as performers who may be in close proximity to laser equipment or laser light.

The multiplicity of roles may diffuse laser safety responsibility. Therefore, for purposes of this Standard, ILDA has defined the following terms and roles.

### 4.1. General Public

The term "General Public" as used herein includes audiences, workers not employed by the Employer (see definition below), and any other persons in the laser show area who cannot be expected to know about laser hazards and/or who cannot be expected to reliably follow instructions to avoid such hazards.

### 4.2. Laser Personnel

The term "Laser Personnel" encompasses persons who have been made aware of the laser's hazards and who can reasonably be expected to follow instructions to avoid such hazards. These persons may include Laser Operators, employees of the Employer (see definition below), and stagehands and performers who have been briefed and who will follow safety instructions.

Laser Personnel **shall** take direction from the Employer, LSO and Laser Operator in laser safety-related matters.

A clear line of authority **shall** be established so that Laser Personnel know their own responsibilities, and know who to report to for any potential safety issues that go beyond their own responsibilities.

If appropriate for their tasks and positions, Laser Personnel **shall** be given authority and responsibility to direct others in order to maintain laser safety; for example, by ordering persons away from prohibited areas.

*Note: For purposes of this Standard, a person is either classified as being in the General Public or as Laser Personnel. If unsure, classify them as General Public.*

### 4.3. Key laser safety roles

This document defines an Employer, a Laser Safety Officer and a Laser Operator. They are the three key roles present in all ILDA Cat A Laser Shows. These are similar to roles defined in the ANSI Z136 series of Safe Laser Use standards.

### 4.3.1. Combined roles

These three roles may be filled by three different persons. Or the roles may be filled by two people or even one person.

For example, if a person purchases a laser show projector, sets it up, and operates it, then that person would simultaneously be the Employer, the LSO and the Laser Operator. They would be responsible for all Employer, LSO and Laser Operator responsibilities listed in this Standard.

### 4.3.2. Role of the Employer

The employer of the Laser Operator (the "Employer") has the fundamental responsibility for the assurance of safe use of lasers. The Employer **shall** establish and maintain an adequate program for the control of laser hazards.

The Employer is defined as someone who is employing, paying or otherwise has control over a person who will 1) perform the role and duties of the Laser Operator, and who will 2) reliably follow any and all instructions from the Employer.

*Note that the Employer may not be an "employer" in the strict sense of the word; that is, a person who pays wages or salary to an employee. But they must have control over the Laser Operator's actions.*

### 4.3.3. Role of the Laser Safety Officer

The Laser Safety Officer (LSO) is an individual designated by the Employer. The Employer gives the LSO the authority and responsibility to evaluate and control laser hazards, and to monitor and enforce the control of such hazards. The LSO either performs the stated task, or ensures that the task is performed.

The Employer delegates to the LSO sufficient authority to suspend, restrict, or stop the operation of a laser system if the LSO deems that laser hazard controls are inadequate.

For the purposes of this Standard, the Laser Safety Officer additionally is the person who designs, produces, supervises or otherwise is in charge of the overall laser safety aspects of a Cat A Laser Show. This person **shall** have general LSO training as well as Cat A-specific training, as described elsewhere in this document.

### 4.3.4. Role of the Laser Operator

The Laser Operator is the person in control of the laser system during normal operation of the laser system. "Normal operation" does not include maintenance or service.

See the section earlier in this Standard, "Trained, competent Laser Operator," for a list of the Laser Operator's duties and responsibilities.

### 4.3.5. Role of the Laser Spotter

The Laser Spotter is a position which **shall** be filled by one or more persons 1) if beams are in areas the Laser Operator cannot see, or 2) in any other situation where the Laser Operator cannot Continuously Monitor all beam positions and termination points.

They **shall** observe the beam path during laser emission. They **shall** monitor for hazards such as stray beams, misaligned projectors, unruly audience members, etc.

All Laser Spotters **shall** be in constant communication with the Laser Operator. The communications method **shall** be reliable and **shall** be clearly understandable under show conditions.

*Note: In a loud environment it can be difficult to hear when using a phone or walkie-talkie. Consider using enclosed headsets instead. Also, when a facility is packed with people, cell phone reception may be spotty. Consider using more reliable wired or wireless connections.*

Each Laser Spotter **shall** communicate any actual or imminent hazards to the Laser Operator.

A clear line of authority **shall** be established so that Laser Spotters know their own responsibilities, and know who to report to for any potential safety issues that go beyond their own responsibilities.

## 4.4. Role of other parties

Other parties such as the venue, the show organizer or producer, bands or other performers, and workers/unions may have laser safety oversight and inputs.

If these parties have concerns, they **should** present these to the Laser Operator, the LSO, and/or the Employer for resolution.

If these parties have authority over the Employer, they may override the Employer if their change increases laser safety. However, they **shall not** override the Employer if their change may make the laser usage less safe in the judgment of the Employer or the person delegated by the Employer (such as an LSO or Laser Operator) to maintain laser safety.

## 4.5. Employer as a sub-contractor

If the Employer is a sub-contractor or is otherwise employed by another party having authority over them, the Employer **should** inform the party of the following, using this wording or similar language:

"I [the Employer] have the fundamental responsibility for safe use of lasers. This responsibility may require actions impacting the laser portion of the show, including not operating lasers if an actual or imminent hazard is present or develops during the

laser emission. Stopping laser output in the event of a hazard is a legal responsibility according to government regulations. It is also a legal and moral responsibility to not cause harm to any person."

The Employer may also wish to include language such as the following:

"We are not responsible for damages or consequences if we stop laser operation, as required by the ILDA Cat A Laser Show Standard and any applicable governmental regulations and venue requirements, due to an actual or imminent hazard that occurs outside our control."

This helps ensure that the Laser Operator can maintain laser safety without being unduly concerned over the aesthetic and financial consequences of stopping laser emissions during a show.

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## 5. Training and Instruction

Training and instruction will allow a person to 1) safely operate a laser or laser system and/or 2) be safe when in an environment where laser light is being used.

In this Standard, **Training** refers to providing information so a person learns useful knowledge and has an understanding of laser safety and procedures. In contrast, **Instruction** refers to telling a person what to do. There may be a basic reason given (“So your eyes don’t get injured”) or the reason may simply be that it is required by their job (“Because we told you so”).

A trained person is more likely to take appropriate actions and to make sophisticated decisions in complex situations.

### 5.1. General

All training and instruction are the responsibility of the Employer. They may delegate this responsibility to a Laser Safety Officer (LSO), Laser Operator, outside training instructor, or other person qualified to understand and transmit knowledge of the safety procedures and laser operation instructions required by the Laser Personnel.

Training and instruction **shall** be provided to each LSO and Laser Operator working with or potentially exposed to light from Class 3B or 4 lasers.

Training and/or instruction **shall** be provided to Laser Spotters and Laser Personnel working with or potentially exposed to light from Class 3B or 4 lasers.

*Note: "Training AND instruction" for LSOs and Laser Operators means a deeper level than "training AND/OR instruction" for Laser Spotters and Laser Personnel. For the latter, simple instructions may suffice such as "notify the Laser Operator if beams are out of position" or "keep out of this area during laser operations." In such a case, training is not required.*

The type of information -- training and/or instruction -- and the level of detail required depends on factors including the person's role, their ability to follow instructions, their potential for exposure, and the hazard potential if exposed.

*Two examples:*

- *A LSO or Laser Operator may be trained in depth on laser hazards and control measures. They can be expected to implement safety measures, in part because they have been trained on the reasoning behind the measures.*
- *In contrast, a performer may be given just a brief training background on laser hazards and then instructions on where to stand during laser emission. The performer can be expected to follow the blocking instructions.*

### 5.1.1. LSO training and instruction

The Employer **shall** provide the LSO with training, or with adequate consultative services instead, on the potential hazards, control measures, applicable standards, and any other pertinent information pertaining to laser safety and applicable standards for the show or display.

This means the LSO **shall** have knowledge, or **shall** work with a knowledgeable and experienced consultant, on the potential hazards, control measures, standards and other information.

LSO training **shall** cover all laser Classes, including Class 3B and 4 lasers.

LSO training **shall** include all topics in the section “Class 3B and 4 training topics” below. In addition, LSO training **shall** include all topics covered or discussed in this Standard which are relevant to the particular show or display.

The depth of training **shall** be commensurate with the nature and degree of potential laser hazards with which the LSO will be working.

The training **should** 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. Such non-beam hazards may include falling equipment and electrical shock.

*Regulatory Note: FDA does not require use of LSOs, nor any specific training of LSOs. LSOs are not mentioned in the FDA variance approval letter Attachment A (general requirements), though LSOs are referenced in Attachment C (only sent with audience-scanning shows).*

### 5.1.2. Laser Operator training and instruction

The Laser Operator **shall** be trained on the operation of the laser, laser system, and associated laser safety devices and features. The training **shall** cover both normal operation, and what to do in case of abnormal operation, misalignment, audience unruliness, and other reasonably foreseeable potential hazards.

In addition, the Laser Operator training **shall** include all topics in the section “Class 3B and 4 training topics” below that are relevant for the show or display.

The duties of the Laser Operator, as detailed elsewhere in this Standard (“Role of the Laser Operator” section) **shall** be described to the Laser Operator, including the need to Continuously Monitor the laser during emission, and to maintain laser safety despite outside pressures.

The Laser Operator does not have to take a formal, classroom-type course. Their training may be done by the LSO of the show or display, or by a similarly qualified person.

A formal classroom-type Laser Operator course, done by an outside company or organization, is suggested but not required by this Standard.

*Regulatory Note: FDA does require the use of laser operators. Form 3147 (variance) states: "All laser light shows shall be under the direct and personal control of trained, competent operators." There appears to be no additional definition or requirement relating to what "trained" means.*

*Regulatory Note: Some jurisdictions may require the Laser Operator to have a certificate of training or similar written document. You may wish to write a list of the training topics covered, both general (operation of the laser, laser system, safety devices, etc.) and topics in the section "Class B and 4 training topics" that were relevant for the show or display.*

### **5.1.3. Laser Spotter training and/or instruction**

Laser Spotters **shall** have adequate training and/or instruction to safely perform their function of determining the location of beams and other potential hazards such as beam misalignment, persons trying to access the beam, etc.

They may be given additional general-purpose laser show safety training.

The duties of the Laser Spotter, as detailed elsewhere in this Standard ("Role of the Laser Spotter" section) **shall** be described to the Laser Spotter, including the need to Continuously Monitor the laser during emission. A Laser Spotter **shall** be trained or instructed to know when and how to notify the Laser Operator and/or to take action on their own if appropriate.

### **5.1.4. Laser Personnel training and/or instruction**

Laser Personnel **shall** have adequate training and/or instruction to safely perform their functions during laser emission. They **shall** be informed of the potential hazards and the control measures for any parts of the show or display where they may be within the separation distance of 3 meters vertical/2.5 meters lateral.

They may be given additional general-purpose laser show safety training.

They **shall** be informed of their responsibility to take laser safety-related direction from the Employer, LSO and Laser Operator.

If given authority to direct others in laser safety-related matters, they **shall** be informed of the scope and limitations of such authority.

### **5.1.5. General Public - cannot be relied upon for safety**

The General Public cannot be expected to be trained nor instructed. They have little or no incentive to follow any training or instruction. For example, they are not employees of the Employer who can be reassigned or disciplined.

For this reason, laser show safety measures **shall not** rely on the ability of the General Public to understand or follow instructions.

*Note: For example, it should be assumed that the General Public may ignore signs such as "Do Not Enter." Because of this, positive measures should be taken so the General Public cannot easily enter a restricted area. These measures may depend on the crowd size and composition. In the "Do Not Enter" example, stanchions can be sufficient for a reserved crowd such as a classical concert audience, while metal barricades would be more appropriate at a music festival.*

## 5.2. Laser safety training topics

Laser safety training **shall** cover the laser-related hazards (beam and non-beam) specific to the show or display laser use, and appropriate to the responsibilities of the role of the person being trained.

The full set of laser safety topics below are primarily intended for training Laser Safety Officers. Laser Operators may be trained on selected topics that are required for their role and the type of lasers in use. Laser Spotters and Laser Personnel may be trained/and or instructed; some of the topics below may be useful for Laser Spotters and Laser Personnel.

Due to the wide range and ever-changing features of laser light show projectors and control systems, the course does not need to teach specific features of any particular equipment or software. The student is expected to apply a concept such as "stop the laser emission," and to determine exactly how this would be performed on their equipment or software.

### 5.2.1. Class 3B and 4 training topics

Training topics for Cat A shows where Class 3B and 4 visible CW lasers are in use **shall** include, but are not necessarily limited to the following:

1. How laser light differs from, and is more hazardous than, conventional light
2. Bioeffects of laser light on the eye and skin. Pulsed lasers **should** be mentioned but most emphasis **should** be on continuous wave (CW) laser bioeffects since this standard only allows use of CW lasers.
3. History (number of occurrences) and examples of laser injuries to technicians and audience members at laser light shows
4. Overview of non-beam hazards of lasers (mechanical/falling, electrical)
5. Specular and diffuse reflections, and how the hazard levels of the reflections may vary
6. How lasers are classified, and what the Classes are, especially concentrating on those Classes which are in use
7. Brief introduction to MPE and NOHD concepts; why they are important
8. Control measures, especially concentrating on those in use
9. How to recognize failure or breach of the control measures
10. Avoiding damage to cameras, video projectors and LED lighting instruments

11. How to anticipate and plan for possible problems (moving stages/trusses, audience unruliness, equipment being moved, changes to performer positions, etc.)
12. Laser safety responsibilities, authority and expectations of the various parties involved, including the Employer, Laser Safety Officer, Laser Operator, Laser Spotter, Laser Personnel, and General Public. Includes chain of command, and reporting requirements when potential hazards develop.
13. Governmental regulations and requirements specific to the person or role being trained. For ILDA Cat A Laser Shows, the training does not need to have detailed information about governmental regulations. But it **shall** include a discussion of how the ILDA requirements differ from governmental regulations, and what additional steps may be required to make a show that is legal for the jurisdictions (country, state/province, city, etc.) of the laser show.

### 5.2.2. Additional topics for Cat A LSOs

The following would not normally be presented to Laser Operators, Spotters or Personnel. But these topics are required for LSOs for Cat A shows; they **shall** also be trained on the following<sup>6</sup>:

14. Irradiance significance, including the difference between power and irradiance for safety considerations
15. Maximum Permissible Exposure and Nominal Ocular Hazard Distance significance and calculations (for CW lasers)
16. Presentation and discussion of the ILDA Category A Laser Show Standard, including the requirements of the Standard
17. (Optional) Presentation and discussion of ILDA's Basic Principles of Lasershow Safety

The calculations may be done using specialist programs or online calculators. The student does not need to memorize equations, or do math in their head or on paper.

### 5.2.3. Optional topics for general (non-Cat A) LSOs

These optional topics for LSO training are not required by this Standard since they cover topics beyond the Cat A Standard. However, these topics will be useful if the student designs or supervises shows more complex than an ILDA Cat A Laser Show. Also, some of these topics are listed by ANSI, Arizona or others as topics suggested or required for their LSOs.

18. Fundamentals of laser operation (how laser light is generated; how lasers work in general)
19. Laser safety standards and organizations

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<sup>6</sup> General-purpose LSO training required by the ANSI Z136 "Safe Use of Lasers" standards may cover more, or different, topics than are required by this Cat A standard. ILDA has selected topics which are most relevant to laser light show LSOs, and has deleted topics that are not relevant such as non-visible laser hazards.

20. Greater detail on governmental regulations and how to fill out and submit variance forms and other government-required forms and documents
21. Hazards of laser light outdoors, including FAA flight zones
22. How to fill out U.S. FAA forms (or similar forms for students from other countries)
23. Hazards of audience scanning. This is an introduction only; the beginning LSO student cannot do safe audience scanning without significant additional training.
24. Types and limitations of laser power and irradiance meters

### 5.3. Laser safety training course requirements

LSOs **shall** take a formal, classroom-type laser safety course (this may be in-person or online). LSOs for Cat A shows **shall** cover items 1-17 in the previous section. Persons who want to be LSOs for more complex laser shows (beyond Cat A) should additionally cover items 18-24.

The course presentation **shall** be in sufficient depth to adequately cover the topics.

Optionally, non-LSO students (Laser Operators, Spotters and Personnel) can take a laser safety course that discusses topics needed for their work, and which goes into sufficient depth considering the nature and degree of potential laser hazards with which the student will be working. While a formal, classroom-type course is not required for non-LSO persons, it is suggested for Laser Operators.

The course **should** solely or primarily cover laser light show safety (as opposed to general-purpose laser safety). As of mid-2022, such lightshow-specific courses are offered by ILDA and others, including Laser Safety Services and LVR Ltd.

*Note: A general-purpose laser safety course may not be appropriate or sufficient to cover laser light show hazards and control measures. Such general-purpose courses include those that concentrate on industrial or medical laser safety, and that spend significant time on hazards of laser radiation outside the visible region. Even if a general-purpose laser safety course discusses some light show topics, 1) the topics may not be discussed in necessary depth for those working on laser shows and 2) it may be counterproductive for the laser show student to sit through numerous uses and types of lasers that they will never be using.*

#### 5.3.1. Course presented live, classroom-style

The course **shall** be presented using a live instructor, either in-person or online via video conferencing. This allows course materials such as slides and demonstrations to be viewed by the student. This also allows the instructor to interact with students, to have a general idea whether the student is paying attention, is understanding the material, etc.

#### 5.3.2. Testing

The course **shall** include a meaningful test, to determine the student's retention and application of the course material.

Test questions **shall** include both factual knowledge such as MPE levels, and applied knowledge such as "what to do in this situation".

### 5.3.3. Certificate proving course completion and test passed

The student **shall not** receive any type of certificate or acknowledgement of taking the course until the test is passed. The suggested term for a certificate is "Certificate of Completion."

*Note: Because of legal considerations, the term "certified" should not be used in the name of the course or on the certificate. This is because "certified" may put the legal onus on the organization behind the course, if there is a problem with a laser show operated by the student. (E.g., this makes it seem that the organization "certifies" or stands 100% behind the student.)*

*Instead, a "Certificate of Completion", which notes that the student took the course and passed a test, is more appropriate.*

If the course topics are limited to laser light show safety, the certificate **shall** reflect this limitation, by including a phrase such as "Laser Safety Officer for Laser Lightshows".

For LSOs who are supervising Cat A laser shows, and who take LSO courses presented after this Standard is enacted by ILDA, the certificate or acknowledgement **shall** state "Includes ILDA Category A Laser Show Standard requirements".

*Note: This helps to distinguish LSOs who passed a course prior to enactment of this Standard, from a more up-to-date course that includes presentation of the requirements of this Standard. Note that the Standard requires Cat A LSOs to be trained on the Cat A requirements.*

### 5.3.4. Retake if test is not passed

If the test is not passed, the student **should** be allowed to retake the course at a lower cost or no cost.

The student in a retake **should** go through the entire course again. They **shall** be given a test with questions generally similar to the original test, but with different answers, numbers in calculations, etc. so that the first test cannot be used as a guide to the second.

### 5.3.5. Refresher course for LSOs trained prior to the implementation of this Standard

This section applies to persons who took, and passed, laser show-specific LSO training prior to the enactment of this Standard, and who will be designing or supervising Cat A laser shows.

Such persons **shall** be given the opportunity to take a refresher course that concentrates on the ILDA Cat A standard's requirements, and the discussions in the

standards' appendices. The refresher course may be shorter and less costly than the original LSO course.

A test **shall** be given at the end of the refresher course, with some questions similar to those on the regular (full) laser show LSO course and others that refer specifically to important aspects of the ILDA Cat A standard. If this test is passed, then the student **shall** receive a LSO certificate or acknowledgement with the added phrase "Includes ILDA Category A Laser Show Standard requirements".

*Note: This ensures that a person who became an LSO prior to the Cat A standard, can get up to speed on the standard and can also get recognition (the certificate) that they have this specific knowledge.*

*It also allows others such as clients and regulators to identify LSOs with trained Cat A knowledge from those who have not had formal Cat A training.*

*ILDA will allow a one-year grace period from the date of adoption of the Cat A Standard, during which passing an LSO training course is still required -- but not necessarily a course which covers the Cat A Standard.*

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## 6. Appendix: Discussion of topics in this Standard

This Appendix gives background information on considerations which were discussed in deciding on the limits of an ILDA Cat A Laser Show. This Appendix is NOT part of the requirements and recommendations of the Standard; it is informative only.

### 6.1. Laser power limitation

The 6-watt limitation was selected because it is in the range where materials may be damaged but are unlikely to combust. Higher powers were excluded because they require more care in beam positioning and use to avoid damage to materials and clothing.

6 watts is sufficient for indoor laser shows up to the size of a hotel ballroom. Larger areas such as indoor and outdoor arenas would probably require a laser show with greater power and safety considerations than those of an ILDA Cat A Laser Show.

#### 6.1.1. 6 watts maximum per beam

Some laser projectors may have multiple apertures; for example, projectors emitting parallel linear lines of laser light. One beam comes out of each aperture.

The 6-watt limitation is per beam. So for the example projector, each parallel beam can be 6 watts maximum.<sup>7</sup>

### 6.2. Terminated beams

Prohibiting unterminated beams is a reasonable restriction for an ILDA Cat A Laser Show.

Shows in the U.S. with outdoor unterminated beams would require notification with FAA, and receipt of a letter of non-objection from FAA. Filing and complying with FAA is more complex, and is thus beyond the limited goals of the ILDA Cat A Laser Show Standard.

### 6.3. Anticipate problems, and plan for mitigation

A review of laser light show accidents and incidents -- those involving the public and not just technicians backstage -- shows a consistent pattern. Laser light went where it was not supposed to because of a foreseeable situation that was not adequately planned for.

ILDA believes that a key part of laser safety is not only traditional control measures, but also anticipating problems and planning how to mitigate them.

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<sup>7</sup> Some persons may be concerned about two beams entering the eye at the same time. Recall that if the beams are separated even by a small distance (e.g, the viewer sees them as two different "dots"), they will hit different parts of the retina. The laser heating will not be additive.

The following examples indicate the importance of pre-planning what to do in a laser show if reasonably foreseeable things go wrong.

### **6.3.1. Examples of foreseeable problems**

Here are some examples of actual incidents that, for the most part, could have been planned for. (If not for the specific issue, then for the general problem of "beams might go where they are not supposed to be".)

- A movable stage set that was placed by stagehands in the wrong position, so audience members were exposed to laser light (on national television)
- Audience members being unruly or deliberately trying to access the beam
- Mylar confetti being unexpectedly shot off in the path of a beam (this involved a pulsed Nd:YAG where a single reflected pulse was 15 times the MPE at the audience position)
- A heavy 70-watt laser being used outdoors that tilted after rain softened the ground underneath, causing the beam to come close to audience members
- Performers or stagehands accidentally bumping into laser equipment and thus changing the beam direction and location
- A motorized truss with 12 video projectors being moved through the beam path, resulting in over \$1,000,000 worth of unrepairable damage to the video projectors
- A performer who, onstage, tripped over what was claimed to be a laser, had bright light in their eyes, and received an apparently serious eye injury
- A curtain being lowered into a Class 4 beam which started a fire that damaged the theater

What made many of these incidents worse was that the Laser Operator did not stop laser emissions when the laser hazard was first noticed. This goes against safety principles as well as ILDA Cat A Laser Show requirements. Laser light emission should be immediately stopped if there is an actual or imminent hazard of human exposure. This standard requires stopping beam emission (as opposed to attenuation) since it is easy to determine that hazardous beams have been shut off.

Fortunately, there was no reported injury from all but one of these incidents (the tripping performer did receive an eye injury).

Also, note that most of these shows with hazards were more complex ones which would not have qualified as an ILDA Cat A Laser Show anyway; for example, the show with the 70-watt laser or the one where a pulsed Nd:YAG laser was used.

## 6.4. Beam masking

"Beam masking" refers to using hardware or software to block the laser beam from an area where it otherwise has the ability to aim or scan.<sup>8</sup>

- The hardware can be an opaque material such as stiff metal or blackwrap foil. Separate pieces can mark large areas such as masking the top, bottom, or sides of the scan field. Or holes can be cut in the material so the beam can only go through the holes.
- In software, the user can mark out parts of a grid so that the software does not allow the laser beam to be moved to the marked (masked) areas.

Both methods have limitations which are discussed below

### 6.4.1. Hardware masking limitations

Simply taping blackwrap to the front face of a projector may not be sufficient in many situations where a laser beam comes fairly close to an audience or other restricted area.

A mask close to the laser aperture often cannot effectively block the beam at large distances. For example, moving the mask just a millimeter left or right at the aperture can cause a shift of a few meters, at a X meter distance. *[Draft note: Calculate and then insert the exact distance.]*

Calculations and experience have shown that an effective hardware mask may need to be firmly affixed, far from the projector aperture. One show required a distance of 40 inches from the aperture to the mask to be effective. A show in a stadium required an aperture-to-mask distance of 60 inches.

Use of hardware masks also requires the mask to be firmly positioned relative to the laser projector. If the mask or its supporting structure moves, the masked area changes. Even if the mask is firmly affixed, a bump to the projector will re-aim the beam and the mask no longer protects all of the intended area.

### 6.4.2. Software masking limitations

Software masks can be more accurate and effective than hardware masks. For one thing, the software mask is always aligned with the projector. As long as the projector stays fixed, the software mask will always be in the same position within the scan field.

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<sup>8</sup> "Masking" and "attenuation" both describe eliminating or reducing the laser beam's power. "Masking" eliminates the beam -- either the beam is passed or it is not. "Attenuation" refers to reducing the power, or at maximum attenuation, blocking the beam. This Standard only allows masking, since it is easier to determine whether the beam is either blocked or not. Allowing attenuation levels could lead to a situation where some amount of light is passed, but then the question becomes whether the amount of light is sufficiently lowered for safety.

However, a software mask is subject to the limitations of the software quality. For one thing, masking must be done after all other positioning changes -- rotations, translations, perspective corrections -- are done in software. If the overall size of the scan field is changed either in software or in hardware (scanner amp X and Y size controls), then the software mask position changes.

ILDA considers that software masking on high-quality, professional level software is an acceptable alternative to hardware masking. When used properly, software masking may be superior to hardware masking that requires dozens of inches between the projector aperture and the hardware mask.

#### **6.4.3. Masking and the ILDA Cat A Laser Show Standard**

Because masking is so complex, ILDA recommends it be used only for gross masking of the top, bottom, and sides of the scan field, if the scanners can go past the masked area into unsafe areas such as the audience.

For a Cat A show, ILDA does not recommend masking for relatively smaller areas such as balconies.

Because of the difficulty of hitting and masking bounce mirrors, ILDA does not allow bounce mirrors or similar small targets in an ILDA Cat A Laser Show.

### **6.5. Continuous Monitoring of shows**

ILDA initially considered allowing Laser Operators to do other non-laser tasks during shows, such as running lighting or sound consoles, as long as the laser was checked periodically such as every 30 seconds.

However, there have been shows where serious laser safety problems (beams in the audience) have been missed for many minutes because the laser operator was also running non-laser equipment.

Continuous Monitoring and near-instant shutdown can be thought of as a redundant backup to all the other safety measures such as projector mounting, masking, terminated beams, etc. Having Continuous Monitoring minimizes the potential harm, even in worst case scenarios such as a laser being accidentally aimed point-blank into an audience.

ILDA therefore decided that an ILDA Cat A Laser Show prohibits a Laser Operator from doing other non-laser duties during laser emission.

## 6.6. Suggested video recording of every show

This standard suggests video recording of every laser show, and keeping the recordings for one year. The recordings could be accessed upon request by federal, state/provincial, or local officials with statutory authority.<sup>9</sup>

Making such videos indicates the laser company is safety conscious, and is confident in the safety of their shows.

If there is an issue, or a lawsuit from an audience member, the video can serve as evidence. (Note that this may benefit the laser show producer. In a 2009 case, claimed audience injuries were determined to have been due to laser pointers misused by audience members, and were not from the stage laser show.)

Small, low-cost video cameras such as GoPros are ubiquitous. Similarly, the cost of video recording and storage media is minimal.

Thus, it is not a burden for a laser show operator to set up one or more cameras to record every show, and to keep the recordings for one year.

*Note: If FDA were to adopt requirements similar to those in Cat A shows, there would be advantages for them also to require video recording of every show:*

- 1. There is a reduced need for FDA inspectors. In essence, each show "inspects itself" since a video recording exists of each show.*
- 2. If questions are raised about a particular show, or just about general operations, FDA can review the videos to check compliance.*
- 3. Laser show producers and operators know that each show is recorded. Hopefully they will be on their best behavior.*
- 4. Video recording helps support laser show producers and operators against clients who may demand unsafe or illegal laser usage. Such clients can be told "FDA requires us to video each show. Therefore we cannot do the unsafe/illegal effects that you ask."*
- 5. If laser shows are not being recorded, this is prima facie evidence that the laser show producer is not operating as required. They can then be shut down, barred from doing shows, and face other relevant FDA penalties.*

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<sup>9</sup> It is not the intent to allow Authorities Having Jurisdiction to have access to the video recordings. While AHJs may have an interest in reviewing past shows, ILDA's position is that only government officials with statutory authority be given access upon request. All other persons, including AHJs, can review the videos only 1) with consent of the video owner or 2) under court order.

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## 7. Appendix: Record of laser light show safety

This Appendix gives background information about laser light show safety which is relevant to ILDA Cat A Laser Show. This Appendix is NOT part of the requirements and recommendations of the Standard; it is informative only.

### 7.1. Introduction

One of the principles of this Standard is that light from Class 3B and 4 lasers is not permitted to be close to the General Public, and is not permitted to be on Laser Personnel. In other words, "audience scanning" and similar deliberate human exposure is banned.

But one may reasonably ask "What if there is some accidental exposure to laser light? Wouldn't that be dangerous?"

It is true that Class 3B and 4 lasers are extremely hazardous at close range such as in a laboratory, or for industrial use. However, the hazard is different, and lower, under conditions at laser light shows. This is a review of the safety record of laser light shows.

### 7.2. Safety record of laser light shows over 45 years

Since laser light shows began in the mid-1970s, there have been hundreds or thousands of laser shows performed worldwide each day using Class 3B and 4 lasers<sup>10</sup>.

ILDA conservatively estimates that from 1975 to 2020, at least 164 million people have been exposed<sup>11</sup> to 16.4 billion occurrences of laser light in their eyes<sup>12</sup> from laser shows that deliberately scanned onto the audience.

Many of these shows, especially those outside the United States, include audience scanning at levels that appear to be well above<sup>13</sup> the ocular Maximum Permissible Exposure (MPE)<sup>14</sup>.

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<sup>10</sup> Class 3B lasers emitting visible light are between 5 mW and 499.9 mW. Class 4 lasers are those 500 mW and above.

<sup>11</sup> Based on 100 nightclubs/disco worldwide doing audience scanning into patrons' eyes, 100 patrons per night in each club exposed to laser light in their eye, times 365 days a year, times 45 years = 164.24 million persons exposed to laser light in their eyes. This is a conservative estimate.

<sup>12</sup> Based on the beam crossing the eye an average of 20 times per show, with five scans into the pupil per crossing = 100 "pulses" of laser light into the eye per patron per night. The actual number of laser pulses in the eye may be less if patrons took actions such as looking away, blocking the light or closing their eyes if the light was uncomfortably bright.

<sup>13</sup> This is based on observations of actual audience scanning laser shows in Europe and elsewhere. Beams were significantly brighter than U.S.-legal audience scanning shows that were measured to be below the MPE.

<sup>14</sup> The MPE is a concept in the laser safety field, defined as "the level of laser light to which a person may be exposed without hazardous effect or adverse biological changes in the eye or skin." This concept has many facets such as a "reduction factor". The end result is that exposure to laser light levels somewhat above the MPE does not necessarily mean there will be a hazardous effect or adverse changes. It should also be noted that a laser beam's light does spread out. At a close distance a beam may be well above the MPE and thus be hazardous. But at a farther distance the beam's energy has spread out so the exposure (irradiance) on the eye or skin is relatively safer and may even be below the MPE.

After 16.4 billion eye exposures, one might expect there to be a significant number of injury reports in the press, in medical journals and in lawsuits. But ILDA has found a remarkably low number of such reports.

### **7.2.1. Low number of injuries**

ILDA has found approximately five documented cases of audience members<sup>15</sup> being injured by a Continuous Wave laser, over 45 years of audience scanning laser shows.

We have found one documented case during those 45 years of a performer being injured by a light-emitting device that was claimed to be a laser.<sup>16, 17</sup>

About 50 audience members have been injured by a pulsed laser, which is known to be more hazardous.<sup>18, 19</sup> For this reason, the ILDA Cat A Laser Show does not permit the use of pulsed lasers.

### **7.3. Are there unidentified injuries?**

It could be argued that millions of people have some medically detectable change<sup>20</sup> to their retina, caused by exposure at a laser show<sup>21</sup>, which has gone unnoticed by the person involved.

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<sup>15</sup> There have been more injuries to laser show operators and technicians, perhaps on the order of 10 or 20 injuries over 45 years. Most of the reports are from last century, before the advent of small, wall-powered laser projectors needing little or no access or maintenance. And these did not happen during a show, but during setup and maintenance procedures. ILDA considers that this Standard, while it applies primarily to General Public exposure, will also increase safety and reduce exposure for laser light show technicians as well.

<sup>16</sup> This occurred May 19, 2022 to the lead singer of "Five Finger Death Punch." He was injured after stumbling around the stage due to heat exhaustion, and accidentally kicking an onstage device, said by him to be a laser, whose light hit him in the eye. He was treated at a hospital and was released with an eyepatch. ILDA was later told second-hand that the onstage device was a strobe light and not a laser; however, we have not yet been able to confirm whether this is true. At the next concert, June 12, 2022 in Austria, the lead singer was onstage without an eyepatch.

<sup>17</sup> ILDA has been unable to find any other reports of performer laser show injuries in 45 years.

<sup>18</sup> There have been roughly 50 audience members with eye injuries from pulsed lasers; the majority of these at a July 2008 rave near Moscow. Of the Moscow persons, four are said to have serious or permanent injuries. The dangers of pulsed lasers are well known. For that reason, this standard only permits the use of Continuous Wave lasers.

<sup>19</sup> There was a report in mid-September 2022 of 63 persons with eye injuries due to a laser show in Kolhapur, India. ILDA has not been able to obtain details about the claimed injuries. The Indian press has been inaccurate in the past about incidents which were ascribed to lasers, but turned out to be due to lens flare or exposure to ultraviolet lamps or aerosols. However, if there were injuries at the Kolhapur show, we very strongly suspect they were due to a pulsed laser due to the similarity between these injury numbers and those of the 2008 Moscow rave described in a previous footnote.

<sup>20</sup> During the 1960-70s experiments which led to setting MPE levels, the presence or absence of a retinal lesion was done by visual examination. If it was not visible, no change was deemed to have occurred. New techniques such as Optical Coherence Tomography can find much more subtle changes to the retina. Such sub-visual changes may not be permanent, may not adversely affect vision, etc.,

<sup>21</sup> Of course, it would be difficult to determine whether any retinal abnormality was caused by exposure to laser light at a laser show. This has also proven to be difficult in related areas, such as determining if a pilot had retinal injuries from having a laser pointer aimed at his or her aircraft. A study would need to examine volunteers' pupils prior to deliberate exposure to laser irradiances and patterns similar to a laser light show, in order to determine if the laser light caused

It is true that under laboratory conditions and a dark-adapted pupil size of 7 mm, laser light at levels of roughly 10 times the MPE sometimes<sup>22</sup> can cause a change to the retina which is visible under medical examination. Thus, some might argue that the millions of audience members deliberately scanned at laser light shows are walking around with undetected changes in their vision.

Assuming for a moment that laboratory conditions are relevant to laser light show audience exposure, this leads to questions about what level of change is considered adverse or injurious.

If a person does not perceive any change in their vision, has there been any harm? If laser light from audience scanning shows has caused undetectable changes, how does this rank along with health risks from other factors at a laser show, such as loud music causing hearing loss or potential excess alcohol or drug consumption? How does the number and severity of laser show eye injuries rank amongst other public health concerns of the U.S. FDA, U.K. PHE and similar regulatory agencies with limited budgets and resources?

Without going into detail ILDA notes the following:

- Persons at laser light shows take active measures to avoid beams that are too bright and uncomfortable. For example, at shows that are too bright, they look down or away as a beam pattern comes near them. They may even hold up a hand or stand behind a person so that no direct laser light comes into their eye.
- In other words, laser show spectators are not passive subjects strapped in a laboratory chair who are forced to repeatedly look into a direct laser beam.
- If there were millions of people with vision changes due to attending audience scanning light shows, one would expect that some fraction of those people would have significant vision problems leading them to report them to doctors, or to sue light show companies. ILDA has not seen any such reports.

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any changes. The subjects would also need to describe any temporary or permanent changes they detected in their vision.

<sup>22</sup> To be specific, 50% of the time. This paragraph describes laboratory experiments where laser light at short range was aimed at primates with anesthetized eyeballs, using varying power levels, to find the irradiance where 50% of the time, there was a just-barely noticeable retinal lesion. The human MPE was then set to be 10 times lower than that irradiance level.



*Photo of comfortable audience scanning. Note the soft laser beams and that spectators are not averting their vision. Photo taken in the mid-1990s at a trade fair in Rimini, Italy.*

#### **7.4. This Standard bans exposure**

We have discussed the fact that many laser light shows, in the past and at present, scan audiences with laser light estimated to be far in excess of the Maximum Permissible Exposure. We have discussed the lack of documented laser light show injuries to audience members and performers from high-powered Continuous Wave lasers.

Recall that the ILDA Cat A Laser Show Standard does not allow any human exposure to light from Class 3B and 4 lasers. It also limits the maximum beam power to be 6 watts.

Therefore, even if there is accidental audience exposure from a 6-watt continuous wave beam at an ILDA Cat A Laser Show, the 45-year record of laser shows indicates it is highly unlikely for there to be a hazardous effect or adverse biological change to the retina or to a person's vision under the laser show conditions: being relatively far from the laser aperture, not deliberately staring into the beam, etc.

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## 8. Appendix: Checklist

This Appendix is a checklist to help ensure the requirements of an ILDA Cat A Laser Show are met. This Appendix is NOT part of the requirements and recommendations of the Standard.

The checklist text is a summary and is not to be fully relied on. The text in the main sections of the Standard (e.g., not the Appendices) contains the complete conditions of the requirements and recommendations.

### 8.1. Laser show operations

- Use only lasers emitting visible light (between 400 nm and 700 nm)
- Use only continuous wave lasers -- no pulsed lasers
- Any use of Class 1, 2 and 3R lasers must be consistent with manufacturer instructions and warnings
- Do not use lasers capable of emitting over 6 watts from any single beam.
- In the U.S., only use laser projectors and equipment certified to FDA, with an approved and active variance. Outside the U.S., use laser projectors and equipment approved for use under the laws of the jurisdiction.
- Use only front or rear screen projections; beams in the atmosphere or with added haze, smoke or fog; reflection/diffraction effects created at the projector, and terminated beams.
- Do NOT use audience scanning, intentional illumination of persons, unterminated beams, or bounce mirrors/gratings.
- This Standard may not be appropriate for shows in private homes and small rooms, or shows in large-scale venues.
- No unterminated beams, or beams that go into navigable airspace
- All beams and termination points **shall** be visible to the Laser Operator (and Laser Spotter if used)
- No human exposure or audience scanning
- Separation distances: Beams **shall** be at least 3 meters (9' 10") surfaces where General Public persons are reasonably expected to stand, and at least 2.5 meters (8' 2") below or in lateral separation to places where General Public persons are permitted to be
- For Laser Personnel, laser light may come near to a person if they have been briefed on the beam and light locations and if they can avoid such locations in the course of their reasonably expected movements
- No scanning onto a balcony (unless there is at least a 2.5m separation between the beams and where General Public persons are permitted to be)
- No unsafe reflected beams

- No added bounce or diffraction mirrors
- Securely mount lasers and other components affecting beam location, power, or divergence
- Restrict access to, and/or use warning signs for, areas which may contain light from Class 3B or 4 lasers.
- No electromagnetic interference with projectors, scan heads or control systems
- Mask beams to prevent them from going into prohibited areas
- Prevent uncontrolled damage to materials
- Maintain laser safety at all times including setup, alignment, rehearsal, performance and tear down
- The Cat A show **shall** be designed by a person who has passed a Laser Safety Officer training course covering specified laser light show topics and the Cat A Standard.

## 8.2. Laser Operator duties

- The show **shall** be under the direct and personal control of a trained, competent Laser Operator who ...
- ... **shall** be 17 years of age or older
- ... **shall** be under the control of the Employer (see definition elsewhere)
- ...**shall** receive adequate training and instructions provided by the Employer or LSO
- ...**shall** have the authority and responsibility to maintain laser safety despite outside pressures
- ... can see all beams during laser emission, or is in continuous contact with one or more Laser Spotters such that the entire group can see all beams
- ... **shall** Continuously Monitor the lasers, and **shall** have no other non-laser task during laser emission. This is a critical requirement since Continuous Monitoring is a "last resort" if other laser safety measures fail.
- ... can use remote monitoring via video or similar means for relatively small, specific laser areas not directly visible to the Laser Operator
- ... **shall** have immediate access to one or more e-stops or similar controls (software on/off buttons) which can shut off selected lasers, or all lasers.
- ... **shall** mitigate the hazard, or **shall** stop laser emissions, in case of an actual or imminent laser safety hazard.
- ... **shall** stop all laser emissions in case of emergency such as panic, fire alarm or a shooting.
- ... **shall** immediately stop laser emissions upon request of an Authority Having Jurisdiction.

## 8.3. Changes, and planning for the unexpected

- Do not add to or change laser effects or operation during the show. Only operate planned effects.

- Anticipate problems, and plan for mitigation. This is very important. Most reported laser show incidents and accidents could have been foreseen and been planned for.

#### 8.4. Record-keeping and notice

- Keep a written or electronic log of the date and location of all laser emissions, including setup, alignment, rehearsals, and performances.
- Record any incidents or accidents in the log.
- Each record in the log **shall** be kept for at least one year from the date of laser emission stated in the record.
- It is suggested (but not required) to record each show using video, with sufficient resolution and quality to show all beam locations and termination points.
- Give notice to relevant authorities as per legal requirements. Be in compliance with applicable regulations.

The remainder of this Appendix is not so much a checklist of things to do, as it is a list of items to be aware of while planning and performing the laser show.

#### 8.5. Roles of various entities at laser shows

- The General Public is all persons in the laser show area who cannot be expected to know about laser hazards and/or cannot be expected to reliably follow instructions to avoid such hazards.
- Laser Personnel consists of persons who have been made aware, through training or instructions, of laser hazards and who can be reasonably expected to follow safety instructions.
- The person who controls, hires or otherwise employs the Laser Operator is called the "Employer". They have the fundamental responsibility for safe laser use. They must establish a program to control laser hazards.

The Employer may designate a person to evaluate and control laser hazards; this is the Laser Safety Officer (LSO). The LSO also monitors and enforces the control of laser hazards. The Employer delegates to the LSO sufficient authority to suspend, restrict, or stop the operation of a laser system if the LSO deems that laser hazard controls are inadequate.

- The three roles above, Employer, LSO and Laser Operator, may be combined such that a single person has all three roles, or two people share some of the roles.
- Roles **shall** be clarified so it is clear what duties, responsibilities, and authority each person has.
- One or more Laser Spotters are optional. They assist the Laser Operator with Continuous Monitoring of the laser beam locations, and any potential hazards.
- A Laser Spotter must be in instant or near-instant (within a few seconds) communication with the Laser Operator.

- If a Laser Spotter sees an actual or imminent hazard, they will either communicate with the Laser Operator who will stop laser emissions, or (if they have the authority) the Laser Spotter will stop laser emissions on their own.
- If any other parties such as the venue, the show producer, the band or performer, workers or union members have concerns, present these to the Laser Operator, the LSO and/or the Employer for resolution.
- These other parties may override the Employer if their concern or change increases laser safety. But they **shall not** override if in the judgment of the Employer, LSO or Laser Operator, the concern or change may make laser usage less safe.
- Contracts **should** have clauses protecting the Employer against retribution if laser emission must be stopped due to safety concerns and/or regulatory requirements.

## 8.6. Training and instruction

Note that "training" provides detailed information and reasons for doing things. "Instruction" refers to telling a person what to do and perhaps a basic reason why.

- Training and instruction **shall** be provided to each LSO.
- Training and/or instruction **shall** be provided to each Laser Operator, Laser Spotter and Laser Personnel.
- The depth of training and/or instruction depends on the person's role, their ability to follow instructions, their potential for exposure, and the level of exposure.
- The LSO **shall** have training and instruction on topics specified elsewhere in the Standard.
- The person who designs, produces, supervises or otherwise is in charge of the overall laser safety aspects of the show **shall** have LSO training.
- The Laser Operator, Laser Spotter and Laser Personnel **shall** have training and/or instructions on topics specified elsewhere in the Standard.
- The General Public cannot be relied upon to understand or follow instructions.
- A list of laser safety training topics is provided.
- Laser show safety training **should** be specific to laser lightshows (no need for industrial, medical, non-visible lasers, etc.)
- Laser show safety training does not need to be specific to how any particular laser projector or control system works; instead, the training provides general guidance
- Laser show safety training **should** be with a live instructor, in-person or online via Zoom or similar.
- LSOs taking laser show safety courses **shall** be tested on factual and applied knowledge, and **shall not** receive any type of certificate or acknowledgement of the course until the test is passed.
- If the person does not pass, they **should** be afforded the opportunity for a retake at low or no cost, using a different test than the first time.



