Chapter 6.2
Laser safety and health

This could be you . . .

Following safe practices has paid off. JSC has no recorded laser incidents.

1. Applicability of this chapter

You are required to follow this chapter if you operate lasers or supervise anyone who operates lasers. At this time, laser pointers are exempted from the requirements of this chapter. (See JSC Safety Alert 99-009, "Safety Hazards of Laser Pointers.")

2. Laser classes

JSC uses the laser classes in ANSI Z136.1, "American National Standard for Safe Use of Lasers:"

a. Class 1 laser system is:

1. Considered to be incapable of producing damaging radiation levels during operation.
2. Exempt from any control measures or other forms of surveillance.

b. Class 1M laser system is:

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

c. Class 2 laser system is:

1. Emits in the visible portion of the spectrum (0.4 to 0.7 μm), and
2. Eye protection in normally afforded by the aversion response.

d. Class 2M laser system:

1. Emits in the visible portion of the spectrum (0.4 to 0.7 μm), and
2. Eye protection is normally afforded by the aversion response for unaided viewing.
3. Is potentially hazardous if viewed with certain optical aids.

e. Class 3R laser system (medium-power):

1. May be hazardous under some direct and specular reflection viewing condition if the eye is appropriately focused and stable, but the probability of an actual injury is small.
2. Will not pose either a fire hazard or diffuse-reflection hazard.
3. **Note: Any laser product previously labeled as a Class 3A product can safely be treated as Class 3R if the beam diameter is less than 7 mm.**

f. Class 3B laser system (medium-power): May be hazardous under direct and specular reflection viewing conditions, but is normally not a diffuse reflection or fire hazard.

g. Class 4 laser system (high-power):

   1. Is a hazard to the eye and skin from the direct beam, and
   2. May pose a diffuse reflection or fire hazard.
   3. May also produce laser generated air contaminants (LGAC) and hazardous plasma radiation.

3. Requirements for working with lasers

You shall follow these requirements when you operate any Class1M, 2M, 3R, 3B, or 4 lasers:

a. When you operate any Class 1M, 2M, or 3R laser system, you shall contact the JSC Laser Safety Office at (281) 483-6726 for a laser hazard evaluation. The JSC Laser Safety Office will determine any additional safety requirements and training necessary for the use of the laser system.

b. When you operate any you operate any Class 3B, or 4 laser system, you shall follow these requirements:

   1. Register these lasers on JSC Form 44B and get approval for use from the JSC Laser Safety Office at (281) 483-6726. Upon evaluation, the Laser Safety Officer (LSO) may require that a person who has substantial laser training be designated as the area Laser Safety Officer for your area.

   2. Each of the above lasers shall have an approved JSC Form 44B from the LSO and the Radiation Safety Committee.

   3. Each of the above lasers shall have an approved JF1023 “Nonionizing Radiation Training & Experience Summary” from the LSO.

c. Follow ANSI Z136.1, ANSI Z136.2, ANSI Z136.6, 21 CFR 1040.10, “Laser products,” and 21 CFR 1040.11, “Specific purposes of laser products.”

d. If you modify any laser, you shall submit a new JSC Form 44B for LSO approval.

e. Don’t operate a laser unless you are certified to do so by the LSO.

f. Know the hazards and hazard controls of each laser you operate. You shall take other precautions if:

   1. The target material could vaporize into a toxic substance.

   2. The laser uses toxic dyes as a lasing medium.

   3. The laser components cause radiation such as x ray, ultraviolet, infrared, or radio frequency.

   4. The laser could reflect off a smooth surface; e.g., glass, metal, or glossy paint.

g. Lasers have high-voltage power supplies. Take precautions to avoid being shocked.

h. Operate lasers with a beam stop.

i. Don't exceed the maximum permissible exposure (MPE) values found in ANSI Z136.1.

j. Tell all visitors in your laser area what the laser hazards are and what safety requirements they need to follow. Visitors shall also:

   1. Be under the direct supervision of at least one certified operator.
   2. Wear required protective equipment.

k. Operate Class 3R, 3B, and 4 lasers only in areas with:

   1. No unplanned reflecting or transmitting surfaces.
   2. Emergency lighting fixtures.
   3. Standard warning placards as described in ANSI Z136.1.

l. Keep all flammable materials away from laser areas unless specifically authorized by an operations or test plan.

4. Engineering controls for laser hazards

Each laser shall have hazard controls that meet ANSI Z136.1. Use engineering controls as much as possible. Also post a current copy of your operating procedures, when applicable. This table tells you which engineering controls are required for each laser class and when they are required. Next to each control is an ANSI Z136.1 paragraph number that offers more details. See the legend below the table for an explanation of the symbols.

Engineering Control Measures	Classifications						
	1	1M	2	2M	3R	3B	4
Protective Housing (4.3.1)	X	X	X	X	X	X	X
Without Protective Housing (4.3.1.1)	LSO shall establish Alternative Controls						
Interlocks on Removable Protective Housings (4.3.2)	Δ	Δ	Δ	Δ	Δ	X	X
Service Access Panel (4.3.3)	Δ	Δ	Δ	Δ	Δ	X	X
Key Control (4.3.4)	--	--	--	--	--	●	X
Viewing Windows, Display Screens and Collecting Optics (4.3.5.1)	Assure viewing limited < MPE						
Collecting Optics (4.3.5.2)							
Fully Open Beam Path (4.3.6.1)	--	--	--	--	--	X NHZ	X NHZ
Limited Open Beam Path (4.3.6.2)	--	--	--	--	--	X NHZ	X NHZ
Enclosed Beam Path (4.3.6.3)	None is required if 4.3.1 and 4.3.2 fulfilled.						

Remote Interlock Connector (4.3.7)	--	--	--	--	--	●	X
Beam Stop or Attenuator (4.3.8)	--	--	--	--	--	●	X
Activation Warning Systems (4.3.9.4)	--	--	--	--	--	●	X
Indoor Laser Controlled Area (4.3.10)	--	*	--	*	--	X NHZ	X NHZ
Class 3B Indoor Laser Controlled Area (4.3.10.1)	--	--	--	--	--	X	--NHZ
Class 4 Laser Controlled Area (4.3.10.2)	--	--	--	--	--	--	X
Outdoor Control Measures (4.3.11)	X	* NHZ	X NHZ	* NHZ	X NHZ	X NHZ	X NHZ
Laser in Navigable Airspace (4.3.11.2)	X	* NHZ	X NHZ	* NHZ	X NHZ	X NHZ	X NHZ
Temporary Laser Controlled Area (4.3.12)	Δ MPE	Δ MPE	Δ MPE	Δ MPE	Δ MPE	--	--
Controlled Operation (4.3.13)	--	--	--	--	--	--	●
Equipment Labels (4.3.14 and 4.7)	X	X	X	X	X	X	X
Laser Area Warning Signs and Activation Warnings (4.3.9)	--	--	--	--	●	X NHZ	X NHZ

LEGEND: X Shall

● Should

-- No Requirement

Δ Shall if enclosed Class3B or Class 4

MPE Shall if MPE is exceeded

NHZ Nominal Hazard Zone analysis required

* May apply with use of optical aids

5. Administrative controls for laser hazards

You may use administrative controls instead of or in addition to engineering controls as required by the LSO. Laser hazard controls shall meet ANSI Z136.1. Also post a current copy of your operating procedures, when applicable. This table tells you which administrative controls are required for each laser class and when. See the legend below the table for an explanation of the symbols.

Administrative and Procedural Control Measures	Classifications						
	1	1M	2	2M	3R	3B	4
Standard Operating Procedures	--	--	--	--	--	●	X

(4.4.1)							
Output Emission Limitations (4.4.2)	--	--	--	--	LSO Determination		
Education and training (4.4.3)	--	●	●	●	●	X	X
Authorized Personnel (4.4.4)	--	*	--		--	X	X
Alignment Procedures (4.4.5)	Δ	Δ	Δ	Δ	Δ	X	X
Protective Equipment (4.6)	--	*	--	*	--	●	X
Spectators (4.4.6)	--	*	--	*	--	●	X
Service Personnel (4.4.7)	Δ	Δ	Δ	Δ	Δ	X	X
Demonstration with the General Public (4.5.1)	--	*	X	*	X	X	X
Laser Optical Fiber Transmission Systems (4.5.2)	MPE	MPE	MPE	MPE	MPE	X	X
Laser Robotic Installations (4.5.3)	--	--	--	--	--	X NHZ	X NHZ
Protective Eyewear (4.6.2)	--	--	--	--	--	●	X
Window Protection (4.6.3)	--	--	--	--	--	X	X NHZ
Protective Barriers and Curtains (4.6.4)	--	--	--	--	--	●	●
Skin Protection (4.6.6)	--	--	--	--	--	X	X NHZ
Other Protective Equipment (4.6.7)	Use may be required						
Warning Signs and Labels (4.7) (Design Requirements)	--	--	●	●	●	X NHZ	X NHZ
Service Personnel (4.4.7)	LSO Determination						
Laser System Modifications (4.1.2)	LSO Determination						

LEGEND: X Shall

● Should

-- No Requirement

Δ Shall if enclosed Class3B or Class 4

MPE Shall if MPE is exceeded

NHZ Nominal Hazard Zone analysis required

* May apply with use of optical aids

6. Requirements for software that controls lasers

Software that controls lasers shall:

a. Provide safety precautions for fast moving-lasers and prevent misdirected lasers.

b. Undergo a hazard analysis as described in Chapter 2.4, "Hazard Analysis," of this handbook and NASA-STD-8719.13, "Software Safety."

7. Requirements for laser enclosures

In addition to laser enclosure requirements in paragraph 4 above, you shall:

a. Use flame-resistant materials or commercial products designed for laser enclosures to enclose Class 4 lasers. Laser levels above 10 watts per square centimeter could set the enclosure materials on fire.

b. Enclose high-pressure arc lamps and filament lamps or laser welding equipment in housings that can withstand the maximum pressure of a lamp explosion or disintegration.

c. Enclose laser targets and optical elements that could shatter during laser operation.

8. Protective equipment for operating a laser

If engineering controls don't eliminate the possibility of overexposure, you shall wear the following protective equipment:

a. Protective glasses or goggles designed to protect you from the laser you are using. Different lasers require different kinds of glasses or goggles. Make sure your protective glasses or goggles are on before you turn on the laser.

b. Skin protection as required.

Note: See ANSI Z136.1 for more details.

9. Training required for laser operations

The JSC Laser Safety Officer determines what, if any, training and experience is commensurate with the laser hazards accessible at each facility. The JSC Laser Safety Officer designates all Area Laser Safety Officers (ALSOs) and certifies all laser operators (LOs). Training Categories are:

a. *Laser operator* – The training and experience required for a certified LO may include, but is not necessarily limited to, the laser training topics as seen in ANSI Z136.1, "Safe Use of Lasers," Appendix D6.2 (1). LOs are required to have initial and refresher training every 2 years thereafter. Training will be documented and maintained by the LO and the JSC LSO. A card will be issued for each laser operator certified by the JSC Laser Safety Officer.

b. *Area laser safety officer* – The training and experience required for an ALSO may include, but is not necessarily limited to, the laser training topics as seen in ANSI Z136.1, "Safe Use of Lasers," Appendix D6.2 (1) and (2). ALSOs are required to have an initial 40 hours of classroom training and refresher training every 2 years thereafter. Training will be documented and maintained by the ALSO and the JSC LSO.

c. *Peripheral personnel (janitors, security, firefighters, waste handlers, etc.)* – The ALSO and the LO are responsible for initial awareness-level laser safety training of peripheral personnel in their area such that they (peripheral personnel) understand the laser hazards associated with their work and are able to take appropriate actions to prevent unnecessary exposure. Awareness-level training shall be documented and a card issued for each person so trained by the JSC Laser Safety Officer. Refresher training is required every 3 years.

d. In addition to the above training categories and topics, you shall be certified to operate a laser as described in Chapter 5.8 of this handbook.

10. Emergency actions for laser mishaps

If laser mishap occurs, follow the emergency procedures in Chapter 3.8, "Emergency Preparedness," of this handbook and the emergency procedures for your facility. You shall contact the LSO as soon as possible to help you investigate the mishap.

11. Outdoor laser operations

The American National Standard Z136.6 provides guidance for the safe use of potentially hazardous lasers and laser systems (0.18 μm to 1 mm), in an outdoor environment. Beams directed into airspace may require coordination with FAA and possibly the U.S. Space Command Laser Clearinghouse.