Chapter 8 – Laser and Microwave Safety (REDACTED)

8.1 Introduction

This chapter describes the Ames Nonionizing Radiation Safety Program. It outlines the safety organization and gives guidelines for the safe use of nonionizing radiation devices. Nonionizing radiation as defined in this chapter includes lasers, microwaves, and radio frequency (RF) energy.

8.2 Applicability

This manual is applicable to: (1) all Ames Employees; and (2) all persons and entities who agree in writing to comply with this manual.

8.3 Responsibilities

8.3.1 Center Director

The Center Director is responsible for all Ames safety programs.

8.3.2 Executive Safety Committee

The Executive Safety Committee (ESC) provides leadership and guides the Center's Safety and Health Programs. In this capacity, the committee uses its authority to make unified policy decisions affecting Ames' injury prevention strategies and approves all major safety initiatives. The ESC charters Ames Safety Committees (Radiation, Explosives, Traffic, Nonionizing Radiation, etc.) and periodically requests committee chairpersons to present information on key topics or report on accomplishments. Problems that cannot be resolved by Center Safety Committees are referred to the ESC.

8.3.3 Nonionizing Radiation Safety Committee

The Nonionizing Radiation Safety Committee (NRSC) is responsible for the following:

1. Advising the Center Director and the Center Executive Safety Committee on matters concerning nonionizing radiation safety.
2. Establishing and maintaining adequate policies and regulations for the control of nonionizing radiation hazards in conformance with applicable regulations and reliable technical guidelines.
3. Approving and authorizing all projects (as defined in this chapter) involving the use of nonionizing radiation devices.
4. Approving the construction and operating procedures for fixed, nonionizing radiation facilities and activities.
5. Investigating nonionizing radiation accidents and reporting findings to the Center Director.
6. Reviewing and revising this chapter as necessary to ensure it is current and that it accurately describes the requirements of the Center.
7. Designating and approving the qualifications of Authorized Laser Users and Authorized Users of Microwave/RF equipment.

8.3.4 Laser Safety Officer (LSO)

The LSO is appointed by the Center Director; responsible to the NRSC for the operation of the Nonionizing Radiation Safety Program, the LSO performs the following tasks:

1. The LSO reviews nonionizing radiation projects for safety and presents the findings to the Committee.
2. The LSO has authority to suspend operations if safety controls are not adequate.
3. The LSO maintains an inventory of nonionizing radiation systems, investi-gates accidents, and reviews the procedures and the physical set-up of the lasers used in the project annually to assure that operations are in compliance with this chapter.
4. The LSO evaluates all laser experiments proposed by laser researchers visiting from other organizations for compliance with Ames Research Center policies and regulations and presents the results of these evaluations to the Nonionizing Radiation Safety Committee for project and user approval.
5. All purchase requests for lasers must be approved by the LSO or substitute to ensure that appropriate tracking of equipment and users is accomplished.
6. The LSO recommends proper protective equipment and eyewear. The LSO or designee signs the approval for the user to receive a Laser Eye Exam based on proposed laser use. The Ames Health Unit maintains a record of employee and contractor laser eye examinations.
7. The LSO maintains records of all nonionizing radiation projects and the inspections of these projects.
8. A copy of the most current American National Standard Z136.1 will be made available to all Authorized Laser Users (ALUs). The users are required to become familiar with those parts applicable to their installation and operations. The provisions of the Standard may be interpreted by the Ames NRSC for local applications.

In the absence of the LSO, the LSO will either designate an Acting LSO or the Chairperson of the NRSC may acts as alternate.

8.3.5 Authorized Users of Nonionizing Radiation

1. The Authorized Laser User or Authorized User of Microwave/Rf Equipment is responsible for compliance with all safety regulations as outlined in this chapter and in the Ames Health and Safety Manual, AHB 1700.1.
2. The ALU is personally responsible for compliance with laser safety regulations in the operation of equipment. Appointment is made by the NRSC after a review of the ALU's qualifications (see Appendix C: Laser User Experience Record).
3. The ALU is personally responsible for ensuring that personnel using lasers under direct supervision or as listed on the ALU's Laser Safety Permit are properly instructed and trained as per section 8.4.8, Training (see Appendix C: Laser User Experience Record). This is also true for personnel using microwave, Rf, or UV radiation under the supervision of an AU.
4. The ALU shall establish and maintain a current list of those personnel authorized to operate specific types of Class 3b and 4 lasers under direct supervision and will furnish a copy of the lists to the LSO.
5. The ALU is responsible for maintaining a current laser inventory, including the location of portable units (see Appendix D: Radiation Safety Committee Laser Inventory). This should include all research lasers in the AU's possession; Class 1 through Class 4 research lasers inclusive.

6. The ALU will not permit the operation of a laser unless there is adequate control of laser hazards as defined by American National Standards Institute (ANSI) Z136.1 or the NRSC.
7. The ALU shall ensure that Standard Operating Procedures (SOPs) are available both at the location where the lasers will be in use as well as submitting a copy of these procedures to the LSO and NRSC for all Class 3b and 4 laser activities. These procedures must be approved by the NRSC and the LSO before being posted with the laser. A copy shall be filed with the LSO.
8. The SOPs shall be submitted for review by the NRSC yearly or whenever any part of the experiment deviates from that described in the SOP(s).
9. The ALU and all laser users shall complete a biannual laser safety training course approved by the ARC LSO.
10. When the ALU believes a laser accident has occurred, the line supervisor and the LSO shall be notified immediately and the person involved shall be sent to the Ames Health Unit. If after hours or if the injury is severe, personnel may be taken by ambulance to local Emergency Rooms for treatment.
11. The ALU shall ensure that all personnel working on their project(s) have laser eye exams and wear appropriate eye protection.
12. The ALU shall ensure that all personnel listed as a worker or junior AU on the AU's Laser Safety Permit(s) are informed that they are required to receive a laser eye exam prior to terminating work at Ames or using lasers at a different organization. It is the individual's responsibility to schedule and receive this exam prior to leaving Ames or at the completion of laser operations at Ames. It should be noted that this exam is to ensure that no eye damage has occurred that the laser worker or operator was not aware of prior to the individual leaving the Center. If the laser worker or user does not receive this exam prior to using lasers at a different organization, Ames may not be able to determine when and where the injury occurred and may not be able to offer compensation for medical surveillance and care for the injury. It is therefore imperative that the laser worker or user have this exam performed prior to leaving or using lasers at a different organization.

8.4 Laser Safety

8.4.1 General Information

1. The use of lasers at Ames is governed by the most current revision of the "Standard American National Standards Institute (ANSI) Z136.1 -for the Safe Use of Lasers." The standard is available on request from the LSO. Application of its provisions at Ames may be modified in general or for specific laser installations by action of the Ames NRSC (in accordance with directives from NASA Headquarters).
2. The use of any Class 3b or 4 laser at Ames shall receive the review and approval of the LSO and the NRSC prior to beginning work or experimenting with the laser.
3. Upon successful completion of an inspection by the LSO or the Committee, the ALU will be issued a permit (ARC 305) to operate the laser for one year or until the operation changes, whichever comes first. The permit must be posted in the area where the laser is used and returned to the Safety Office upon expiration or the Laser Safety Officer informed of the completion of laser operations. (see Appendix A: Laser Safety Permit)

8.4.2 Operational Safety Controls for Lasers

8.4.2.1 Guidelines

All lasers will be operated in accordance with the most current revision of ANSI Z136.1 and the controls specified by the Ames Research Center NIRSC.

8.4.2.2 Laser Classifications

Lasers are classified by the ability of the primary laser beam or reflected primary laser beam to cause biological damage to the eye or skin during intended use. In general, the classification is as follows:

1. **Class 1 Lasers** are considered to be incapable of producing damaging radiation levels and therefore are exempt from any control measures or other forms of surveillance.
2. **Class 2 Lasers** (low power) emit in the visible portion of the spectrum (0.4 _ 0.7 ?m) and eye protection is normally afforded by the aversion or blink response.
3. **Class 3 Lasers** (medium power) are divided into two subclasses, 3a and 3b. A Class 3 laser may be hazardous under direct and specular reflection viewing conditions, but the diffuse reflection is not usually a hazard. A Class 3 laser is normally not a fire hazard.
4. **Class 4 Lasers** (high power) are a hazard to the eye and skin from the direct beam and to the eye from a diffuse reflection. Class IV lasers are also fire hazards.

Note: Refer to the ANSI Z136.1 standard and the Ames Research Center Laser Safety Training Course for a more complete discussion on the classification of lasers.

8.4.2.3 General Operating Controls

1. All lasers must bear a laser hazard classification label.
2. Personnel will not look or cause other to inadvertently look into the primary beam of any class of laser, and shall avoid specular reflections of the beam. This is the most important and most fundamental rule for the safe use of lasers.
3. Class 1 lasers are not considered hazardous and are not controlled. The use of these lasers must be submitted to the NRSC for inventory purposes only. Users of this class of lasers in research need only submit an inventory of lasers to the LSO. It is also recommended that all laser users complete the Ames Laser Safety Training or equivalent.
4. Class 2 lasers are not normally a hazard to personnel. Users of this class of lasers in research need only submit an inventory of lasers to the LSO. It is also recommended that all laser users complete the Ames Laser Safety Training or equivalent.
5. The use of Class 3a lasers will be controlled on a case-by-case basis. The ALU shall contact the LSO to discuss the use of the laser prior to beginning research. We do not currently control the use of Class 3a laser pointers at Ames.

8.4.2.4 General Operating Controls for Class 3b and Higher

1. Laser laboratories and areas must be posted with appropriate warning sign(s) and NASA Laser Permit(s). The LSO for the Center will be consulted to ensure proper posting of laser use areas.
2. Only qualified authorized personnel shall operate lasers or laser systems at Ames.
3. Lasers should be mounted so that the beam path is not at eye level for standing or seated personnel.
4. A laser beam should be terminated at the end of its useful path by a material that is nonreflective and fire resistant (beam dump).
5. Apertures and beam blocks should be used to prevent beams from exiting the intended path in the event of a misaligned, loose, or missing optical component.
6. Aiming the laser with the eye by looking along the axis of the beam should be avoided as this practice has led to the majority of eye injuries in the laser field. Recommended

alternatives to this practice are using low-power class 1 lasers to align the high-power lasers or the beam path can be traced with a paper card while wearing laser goggles.

7. Where feasible, work with laser should be conducted in areas of high general illumination.
8. If the energy output of the laser could damage the eyes or skin, personnel should wear protective equipment (i.e., laser safety eyewear and clothing).
9. When a secondary laser beam can emerge from the rear aperture of a laser, the aperture should be covered. Likewise, any unused beam resulting from the use of a beam splitter should be terminated.
10. All windows, doorways, and opening portals, etc., from the laser lab shall be covered to prevent hazardous laser radiation from being transmitted to outside passages.
11. Personnel must take suitable precautions to avoid other types of hazards associated with the use of lasers (i.e., electrical, cryogenic, toxic, and corrosive chemicals).
12. A specialized local ventilation system is required at laser targets or for laser Doppler velocimeter speed materials if they will produce toxic fumes or gases.
13. Housekeeping is especially important in laser laboratories due to fire and reflective hazards. All combustible materials, flammable liquids, and reflective materials must be properly stored; aisles and exits must be kept clear.
14. Laser electronic firing systems should be designed so that accidental pulsing of a stored charge is avoided. The design should incorporate a "fail-safe" system.
15. The Environmental Services Office (QE) must dispose of chemicals for dye lasers. The ALU, or designate, shall notify the Environmental Services Office (QE) when it is necessary to dispose of any chemical waste.

8.4.2.5 Outdoor Laser Operations

1. The LSO shall conduct an analysis to establish the nominal hazard zone (NHZ), if not available or if not furnished by the manufacturer, as part of the classification documentation.
2. Unprotected, untrained, and unauthorized personnel shall be excluded from the beam path at all points where the appropriate maximum permissible exposure (MPE) is exceeded.
3. Appropriate combinations of physical barriers, screening, protec-tive eye and body wear, or appropriate administrative controls shall be used if personnel are permitted within the NHZ.
4. Directing the laser beam toward automobiles, aircraft, or manned vehicles shall be prohibited within the NHZ.
5. The laser beam path shall not be maintained at or near personnel eye level without specific authorization of the LSO or the NRSC.
6. The beam path shall be terminated where possible.
7. When the laser is not being used, it shall be disabled in a manner that prevents unauthorized use.
8. Only qualified and authorized personnel shall operate the laser or laser system.
9. The operation of Class 3b or 4 lasers or laser systems during rain or snowfall or in fog or a dusty atmosphere may produce hazardous reflections near the beam. In such applications, the LSO shall evaluate the need for and specify the use of appropriate personal protective equipment (PPE).

8.4.3 Laser Warning Signs

1. Design - In accordance with ANSI Z136.1 (1993). Examples of signs are found in Sections 8.6.5, 8.6.6, and 8.6.7.
2. Posting of laser areas/laboratories - Shall be implemented as described in the following table.

Type of Sign	I	II	IIIa	IIIb	IV
Notice	N/A				
Caution		N/A	Caution		
Danger				Danger	Danger

3. Displaying signs and labels - All signs and labels shall be conspicuously displayed in locations where they will best serve to warn onlookers.

8.4.4 Modifications of Laser Systems

Where modifications are made that could change the laser or laser system class and affect its output power or operating characteristic so as to make it potentially more hazardous, the ALU must contact the LSO to ascertain whether any changes are required in control measures.

8.4.5 Medical Surveillance

All personnel who work with Class IIIb and IV lasers or who are permitted by an ALU to be in designated laser control areas must receive an ophthalmologic examination before the laser work begins. The ALU, with the approval of the LSO, will arrange with the Ames Health Unit for the examinations. Follow-up examinations are required as follows:

1. Laser Accidents - Immediately after a confirmed or suspected accident has occurred.
2. End of Employment or Assignment - A follow-up examination is required at the conclusion of employment, or when the employee is not expected to be exposed to laser radiation again at Ames Research Center. It is also highly recommended that personnel receive laser eye exams prior to and immediately following laser use at institutions outside of Ames Research Center.
3. Periodic Exams - At the discretion of the NRSC for personnel working on unusually hazardous experiments or equipment.

8.4.6 Personnel Protective Equipment (PPE)

1. Eye Protection--All personnel protective eye wear shall meet the requirements of ANSI Z136.1 (1993). Protective eye wear shall be made available by the ALU for use whenever personnel could be exposed to levels of laser radiation at or above the MPE established in the ANSI Z136.1 (1993) standard.
   - All laser eye wear must be clearly labeled with the optical density values and the useful wavelengths.
   - All eye wear must be inspected by the user prior to use to ensure serviceability. Lenses with deep nicks or scratches must be removed from service.
   - An inventory of eye wear controlled by each ALU shall be submitted annually to the LSO for review at the time of the laser system inspection.
2. Skin Protection--Protective gloves, clothing, and shields must be used to prevent exposure of the skin to levels of laser radiation at or above the MPEs established in the ANSI Z136.1 (1993) standard.

8.4.7 Associated Hazards

8.4.7.1 Atmospheric Hazards

1. Vaporized target material from high-energy laser cutting, drilling, welding, etc. may be toxic.
2. Gases that flow through laser systems or byproducts of laser reactions such as bromine, chlorine, fluorine, hydrogen cyanide, etc. can be extremely toxic.
3. Gases or vapors from cryogenic coolants may cause freezing, asphyxiation, or become an explosion hazard.
4. Material used as a scattering medium for laser Doppler velocimetry may be hazardous.
5. Material Safety Data Sheets (MSDS) must be available in the immediate work area for any chemical used as part of the project.

8.4.7.2 Explosions

High-pressure arc lamps and filament lamps in laser equipment shall be enclosed in housings that can withstand explosions resulting from lamp disintegration. The laser target and elements of the optical train, which may shatter during laser operation, shall also be enclosed or protected to prevent operator and observer injury. Components such as electrolytic capacitors may explode if subjected to voltages greater than their ratings, with the result that ejected metal may bridge live electrical parts. Such capacitors shall be tested to make certain that they can withstand the highest probable potentials should other circuit components fail, unless the capacitors are adequately contained so as not to create a hazard.

8.4.7.3 Radiation

1. X-rays generated by high voltage (over 15 kV) power supply tubes shall be evaluated and, if necessary, controlled.
2. Ultraviolet radiation emitted from laser discharge tubes and pumping lamps (that is, not part of the primary laser beam) shall be suitably shielded so that personnel exposures are maintained within the threshold limit values specified by the American Conference of Governmental Industrial Hygienists (ACGIH) and the Occupational Safety and Health Administration (OSHA).

8.4.7.4 Electrical

Several electrocutions have occurred during troubleshooting or servicing of laser equipment. In general, the individuals were working alone or personnel working nearby did not know how to administer Cardiopulmonary Resuscitation (CPR). The importance of adequate training and the use of the "buddy system" when working around high-voltage laser power supplies cannot be overstressed. Protective electrical circuit design is also important. The laser resonator and electro-optical elements should be designed so that no exposed metallic element is above ground potential. All employees working on or around electrical components with potentials greater than 42.5 volts must be trained in appropriate electrical safety precautions.

8.4.7.5 Installation

The intended application of the laser equipment determines the method of electrical installation and connection to the power supply circuit (for example, conduit versus flexible cord). All equipment installation shall meet the National Electrical Code requirements.

8.4.7.6 Shock

Live parts of circuits and components with peak open-circuit potentials greater than 42.5 volts and 0.5 mA are considered hazardous. Such circuits require positive protection against contact. For equipment intended for general use, interlock switches (capacitor bleeder resistors, if applicable) or their equivalent shall be installed to remove the voltage from accessible live parts

to permit servicing. Bleeder resistors shall be of such size and rating as to carry the capacitor discharge current without burnout or mechanical injury. Circuits and components with peak open-circuit potentials of 2500 volts or greater shall be adequately covered or enclosed if an appreciable capacitance is associated with the circuits. If servicing of equipment requires entrance into an interlocked enclosure within 24 hours of the presence of high voltage within the unit, a solid metal grounding rod shall be utilized to ensure discharge of high-voltage capacitors. The grounding rod shall be firmly attached to ground prior to contact with the potentially live point. A resistor ground rod (for example, a large-wattage ceramic resistor) may be used prior to application of the aforementioned solid conductor-grounding rod to protect circuit components from overly rapid discharge, but shall not be used as a replacement.

8.4.7.7 Ground

The frames, enclosures, and other accessible noncurrent-carrying metallic parts of laser equipment shall be grounded. Grounding shall be accomplished by providing a reliable, continuous metallic connection between the parts to be grounded and the grounding conductor of the power wiring system.

8.4.7.8 Electrical Fire

Components in electrical circuits shall be evaluated with respect to fire hazards. Enclosures, barriers, or baffles of nonmetallic material shall comply with "Polymeric Materials for Use in Electric Equipment," Underwriters Laboratories Standard UL 746C.

8.4.7.9 Marking

The user shall ensure that each laser is permanently marked with its primary electrical rating in volts, frequency, and watts or amperes. If the laser is intended for use by the public or by personnel untrained in laser safety, and is provided with electrical safety interlocks, warning notices instructing the user not to defeat the interlock should be applied to the device or immediately adjacent to the device.

8.4.7.10 Flammability of Laser Beam Enclosures

Enclosure of Class IV laser beams can result in potential fire hazards if suitable enclosure materials are likely to be exposed to irradiances that exceed I0 W/cm2 for total beam powers exceeding 0.5 W. Flame-resistance materials should be encouraged.

8.4.7.11 Liquid Cryogenic Coolants

In liquid form, these coolants may cause tissue damage if splashed in the eyes or into the shoes. Personnel protective equipment must be worn when handling this material.

8.4.8 Training

1. All personnel who work with Class 3 and 4 lasers must receive laser safety training prior to handling the laser. Initial training is coordinated with the Laser Safety Officer, and it must be documented.
2. Personnel who are visiting Ames from other facilities should take the Ames Laser Safety course, but may be allowed to substitute the training from their facility if they provide documentation of current (within two years) training and the LSO determines that their experience and training is sufficient to be exempted. If the visiting researcher will be submitting a new project to be performed at Ames, they will be required to take the Ames Laser Safety Training as it contains instructions on our procedures for projects. Personnel who do not have current training shall successfully complete the Ames Laser Safety Training Course prior to handling lasers at Ames.
3. Biannual refresher training is mandatory for all personnel who work with lasers.

4. All Ames personnel will be issued a laser operator card (ARC 314) or equivalent certified by the Laser Safety Officer as proof of successful completion of training and medical surveillance requirements. Cards shall be renewed annually (see Appendix H: Laser User Certification Card (ARC 314).

8.5 Microwave/RF Radiation Safety

8.5.1 General Information

The Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz, is given in IEEE C95.1-1991. It covers safe levels involving both controlled and uncontrolled environments. The recommendations are listed in Sections 8.6.9 and 8.6.10.

8.5.2 Authorized User's (AU's) Responsibilities

The Authorized User of microwave/Rf equipment is personally responsible for compliance with the microwave/Rf standard and Ames regulations in all operations. Operations are authorized by the NRSC. AU responsibilities include:

1. Preparation of an initial Safety Review document for new projects or modifications of existing facilities.
2. Providing safety instructions to personnel using equipment under his direction.
3. Prohibiting use of the equipment unless there is adequate control of hazards, including warning signs and interlocks as necessary.
4. Notifying the Radiation Safety Officer within 24 hours when known or suspected overexposure to microwave/Rf radiation has occurred. The Ames Health Unit will examine the person for evidence of injury, including an ocular examination, within 24 hours.
5. Adopting practices that will not intentionally expose an individual to microwave/Rf radiation in excess of the Permissible Exposure Limits (PELs).

8.5.3 Microwave/Rf Project Safety Review

1. Prior to installing new microwave/Rf equipment or modifying existing equipment, a Project Safety Review document must be submitted by the AU to the Laser Safety Officer for review by the Committee.
2. The document should include:
   - A description of the system and its application
   - A diagram showing the beam path
   - Operating parameters
   - Frequency
   - Antenna dimension
   - Power out
   - Antenna type
   - Pulse description
   - Antenna gain
   - Polarization of transmitted wave
   - Standard operating procedures, which will be posted near the equipment and which are designed to minimize hazards to personnel.
3. The project shall be reviewed by the NRSC on an annual basis, or more frequently if the researcher's project deviated from approved standard operating procedures (SOPs).

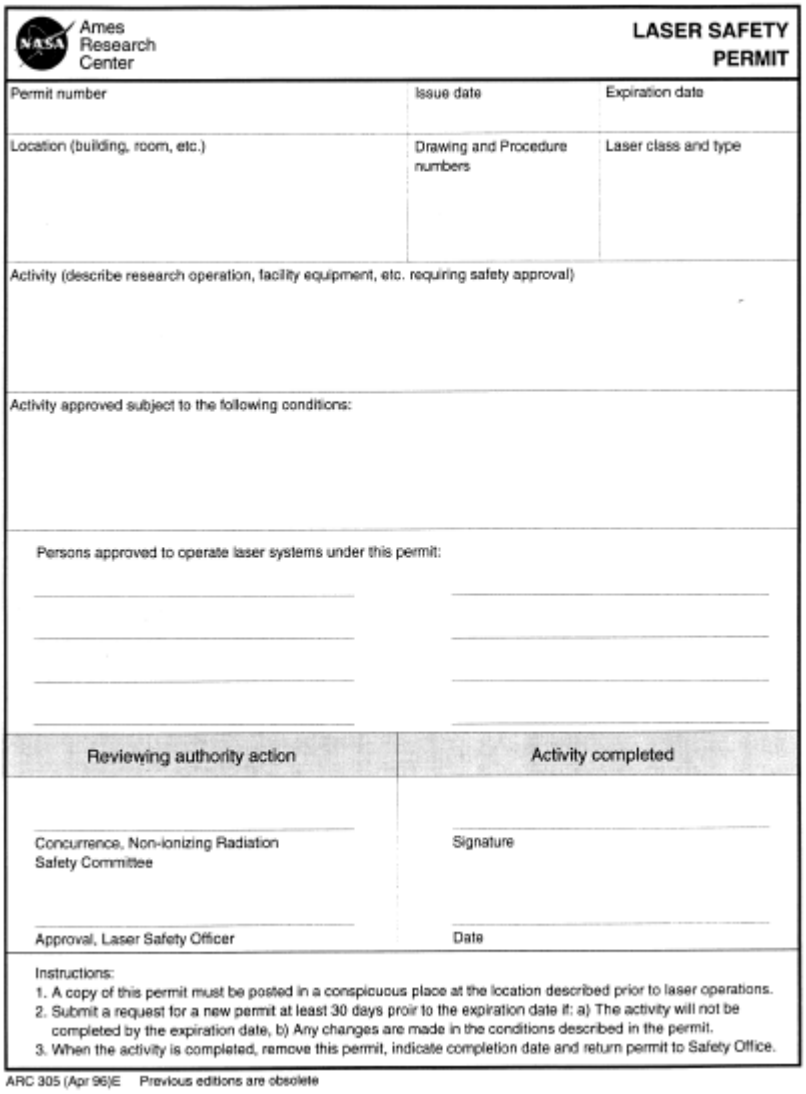
8.5.4 Operational Safety

The following rules apply when Radio Frequency Radiation (RFR) exceeding the PELs is produced by equipment operated within NASA Ames except for household microwave ovens.

1. SOPs must be posted near all operational equipment. The SOP outlines suitable radiation protection procedures. A copy of the SOP is on file in the Safety Division.
2. Only individuals who have been instructed in the potential hazards of microwave/Rf radiation and applicable SOPs are permitted to use the equipment.
3. Microwave/Rf warning signs must be posted to define controlled areas. (see Section 8.6.11)
4. Access to areas where RFR exceeds the PEL must be restricted. When appropriate, physical barriers shall be used.
5. Dummy loads shall be used whenever free-space radiation is not required by the mission.
6. Free-space transmission within buildings is forbidden without prior approval from the Radiation Safety Officer (RSO). As always, appropriate precautions must be taken to prevent overexposure to RFR.

8.6 Appendices

8.6.1 Appendix A: Laser Safety Permit



Ames Research Center

LASER SAFETY PERMIT

Permit number	Issue date	Expiration date
Location (building, room, etc.)	Drawing and Procedure numbers	Laser class and type

Activity (describe research operation, facility equipment, etc. requiring safety approval)

Activity approved subject to the following conditions:

Persons approved to operate laser systems under this permit:

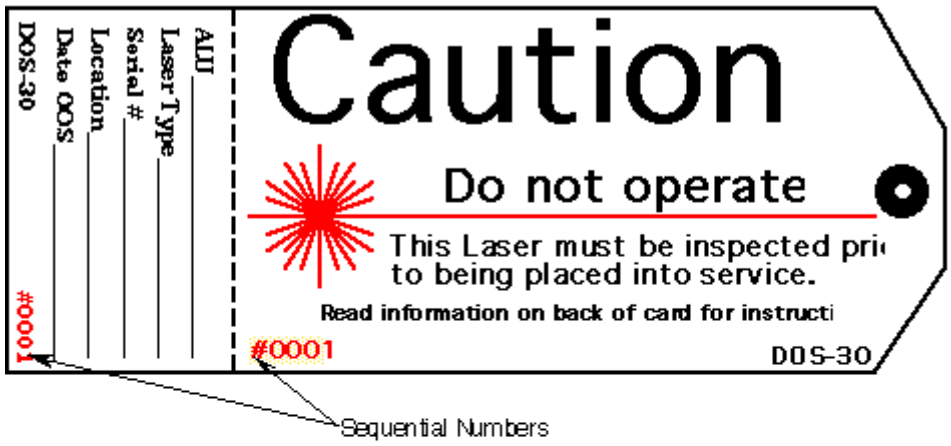
Reviewing authority action	Activity completed
Concurrence, Non-ionizing Radiation Safety Committee	Signature
Approval, Laser Safety Officer	Date

Instructions:
1. A copy of this permit must be posted in a conspicuous place at the location described prior to laser operations.
2. Submit a request for a new permit at least 30 days prior to the expiration date if: a) The activity will not be completed by the expiration date, b) Any changes are made in the conditions described in the permit.
3. When the activity is completed, remove this permit, indicate completion date and return permit to Safety Office.

ARC 305 (Apr 96)E Previous editions are obsolete

8.6.2 Appendix B: Laser Out-of-Service Tag (DOS 30)

Front



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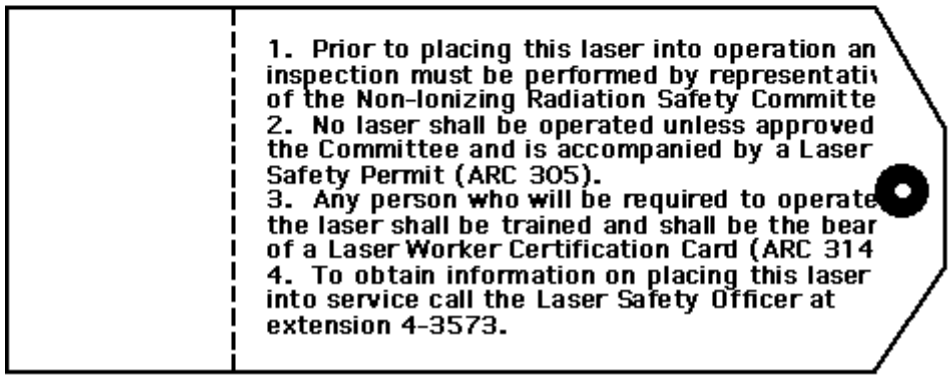


8.6.3 Appendix C: Laser User Experience Record

NAME:	ORG CODE:

TRAINING:				
Type Of Training	Where Trained	Duration of Training	On the Job (Circle One)	Formal Course
Engineering, Physics, Biology, etc.			___Yes ___No	___Yes ___No
Laser Courses			___Yes ___No	___Yes ___No
Laser Safety Courses			___Yes ___No	___Yes ___No

LASER EXPERIENCE			
Type of Laser	Power	Use (chemical analysis, distance measuring, etc.)	Duration of Experience

Receipt Of Regulations

I have read and understood the following material:

( ) ANSI Z136.1 for the safe use of lasers

( ) Ames Health and Safety Manual, Chapter 8/Lasers and Microwave Safety

_____

Signature Date

_____

8.6.4 Appendix D: Radiation Safety Committee Laser Inventory

Hp#:					
Authorized Laser User		Org.		Date	
Class		Bldg.		Room No.	

Description of Laser:			
1. Type		5. Wave Length Emitted	
2. Manufacturer		6. Maximum Output	
3. Model/Serial		7. Beam Diameter	
4. ARC #		8. Beam Divergence	

Other Users of Laser

Description of Use

Safety Features	
1. Shielding	
2. Warning Devices	
3. Interlocks	
4. Special Operating Procedures	
5. Classification Label	

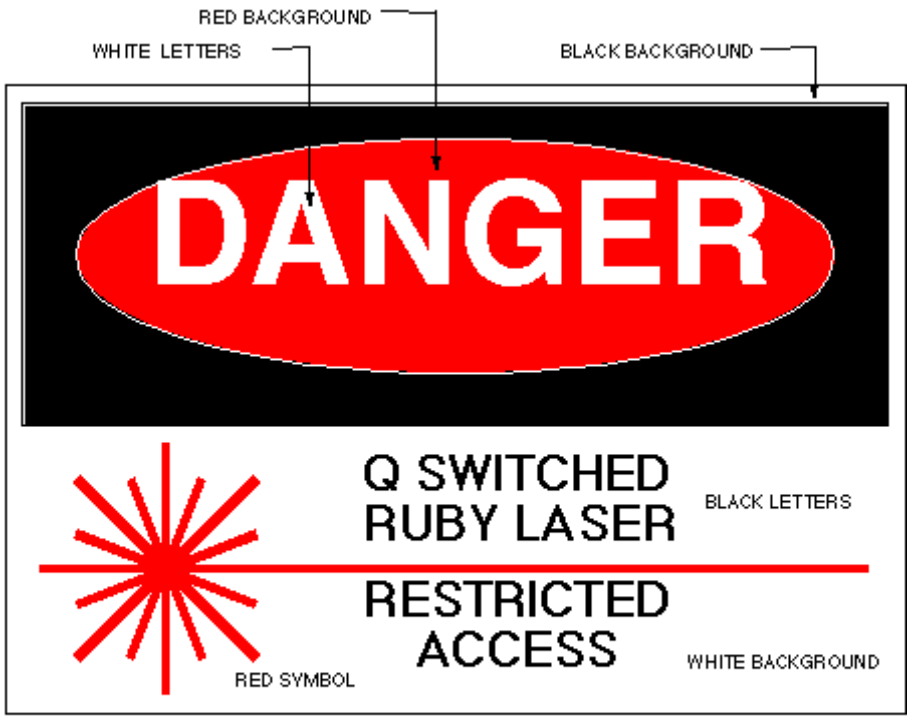
Eye Protection	
1. Type Of Eyewear	
2. Wavelength Marked on Eyewear	
3. Optical Density (OD)	
4. Special Provisions	

Special Hazards

Signature of Person Responsible for Laser Date

Signature of Radiation Safety Officer Date

8.6.5 Appendix E: Class IV Laser Warning Sign



CLASS IV LASER SIGN

8.6.6 Appendix F: Class II Laser Warning Sign

CLASS II LASER SIGN

8.6.7 Appendix G: Laser Repair in Progress Sign

8.6.8 Appendix H: Laser User Certification Card (ARC 314)

NASA Ames Research Center	Laser Worker's Certification
Certified worker (Name)	
Lasers certified to operate (List applicapble lasers and classification)	
Laser Safety Officer (Certidfication with applicable safety regulations)	Date:
Prescribing Document AHB 1700.1/Chapter 8	

ARC 314 (Jul 92)

This certification is void one year from date shown on opposite side, unless revalidated as indicated below. This card must be returned to the Radiation Safety Officer upon termination of duties.

Revalidations

Division Chief	Laser Safety Officer	Expiration date

8.6.9 Appendix I: Maximum Permissible Exposure for Controlled Environments (3 kHz--300 GHz)

Table 1 Maximum Permissible Exposure for Controlled Environments

Part A: Electromagnetic Fields[1]

1	2	3	4	5
Frequency Range (MHz)	Electric Field Strength (E) (V/m)	Magnetic Field Strength(H) (A/m)	Power Density/ E-Field, H field (mW/cm^2)	Averaging Time (E)2, (H)2 or S (minutes)
0.003 _ 0.1	614	163	(100, 1000 000) [2]	6
0.1 _ 3.0	614	16.3/f	(100, 1000 000) [2]	6
3 _ 30	1842/f	16.3/f	(900/f^2, 10 000/f^2) [2]	6
30 _ 100	61.4	16.3/f	(1.0, 10 000/f^2) [2]	6
100 _ 300	61.4	0.163	1.0	6
300 _ 3 000			f/300	6
3 000 _ 15 000			10	6
15 000 _ 300 000			10	616 000/$f^{1.2}$

Part B: Induced and Contact Radio Frequency Currents[3]

Frequency Range	Maximum Current (mA)		Contact
	Through both feet	Through each foot	
0.003 - 0.1 MHz	2 000f	1 000f	1 000f
0.1 - 100 MHz	200	100	100

Note: f = frequency (MHz)

[1]The exposure values in terms of electric and magnetic field strengths are the values obtained by spatially averaging values over an areaequivalent to vertical cross-section of the human body (projected area).

[2]These plane wave equivalent power density values, although not appropriate for near-field conditions, are commonly used as a convenient comparison with MPEs at higher frequencies and are displayed on some instruments in use.

[3]It should be noted that the current limits given may not adequately protect against startle reactions and burns caused by transient discharges when contacting an energized object. See IEEE C95.1 1991 for additional comments.

8.6.10 Appendix J: Maximum Permissible Exposure for Uncontrolled Environments (3 kHz--300 GHz)

Table 2 Maximum Permissible Exposure for Uncontrolled Environments

Part A: Electromagnetic Fields[1]

1	2	3	4	5	
Frequency	Electric Field	Magnetic Field	Power Density	~Averaging Time	
Range	Strength(E)	Strength (H)	E-Field, H-Field	(E)2	S or (H)2
(MHz)	(V/m)	(A/m)	(mW/cm^2)	(minutes)	
0.003 - 0.1	614	163	(100, 1 000 000) [2]	6	6
0.1 - 1.34	614	163/f	(100, 10 000/f^2) [2]	6	6
1.34 - 3.0	823.8/f	163/f	(180/f^2,10 000/f^2) [2]	f^2/0.3	6
3.0 - 30	823.8/f	16.3/f	(180/f^2,10 000/f^2) [2]	30	6
30 - 100	27.5	158.3/$f^{1.668}$	(0.2, 940 000/$f^{3.336}$) [2]	30	0.0636$f^{1.337}$
100 - 300	27.5	0.0729	0.2	30	30
300 - 3 000			f/1 500	30	
3 000 - 15 000			f/1 500	90 000/f	
15 000 – 300 000			10	616 000/$f^{1.2}$	

Part B: Induced and Contact Radio Frequency Currents[3]

Frequency Range	Maximum Current (mA)		Contact
	Through both feet	Through each foot	
0.003 - 0.1 MHz	900f	450f	450f
0.1 - 100 MHz	90	45	45

Note: f = frequency (MHz)

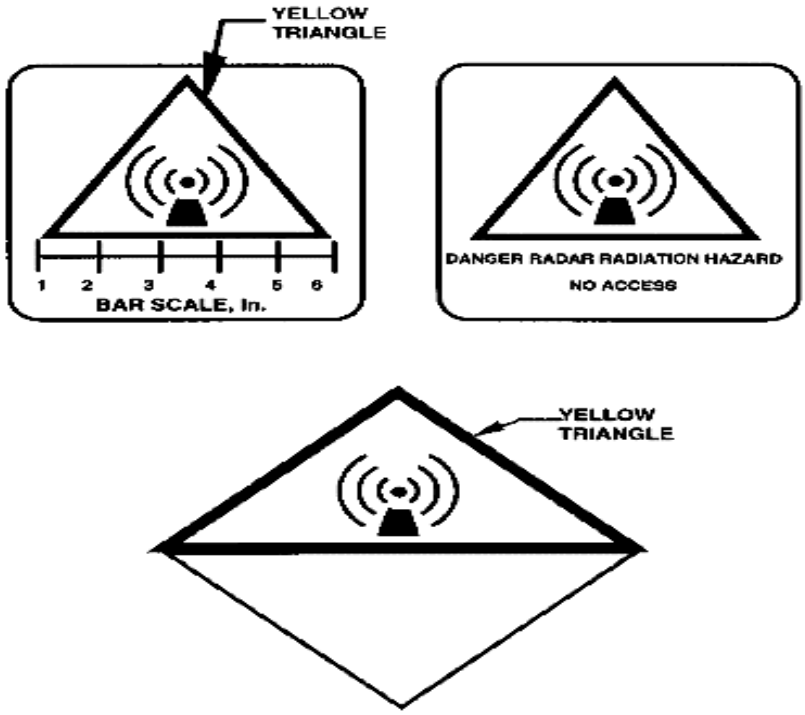
[1]The exposure values in terms of electric and magnetic field strengths are the values obtained by spatially averaging values over an areaequivalent to vertical cross-section of the human body (projected area).

[2]These plane wave equivalent power density values, although not appropriate for near-field conditions, are commonly used as a convenient comparison with MPEs at higher frequencies and are displayed on some instruments in use.

[3]It should be noted that the current limits given above may not adequately protect against startle reactions and burns caused by transient discharges when contacting an energized object. See IEEE C95.1 1991 for additional comments.

8.6.11 Appendix K: Microwave/RF Warning Signs

MICROWAVE/RF WARNING SIGN



8.6.12 Appendix L: Laser Safety Inspection Form (ARC 313)

Ames Research Center

LASER EYE EXAM

To: Safety Office, Health Unit

Date

From

Subject: Authorization for Laser Eye Examination

The work performed by the employee listed below requires wearing laser safety eyewear. A laser eye examination is required.

Employee Name (Type or Print) | Phone

Organization Code | Mail Stop

Employee:
I understand that in receiving a laser eye exam that I must also complete an exit exam. For students and employees who know their completion dates at Ames an exit examination must also be scheduled at the time on the initial exam.

Branch Chief or higher (signature)

Employee (signature)

Approved: Representative - Safety, Health and Environmental Services Office | Date

The above contract employee or student is eligible for a laser eye exam as required by the work assigned to and it should be furnished at government expense.

Contract number | Contract Monitor

Location and date of examination (entrance)

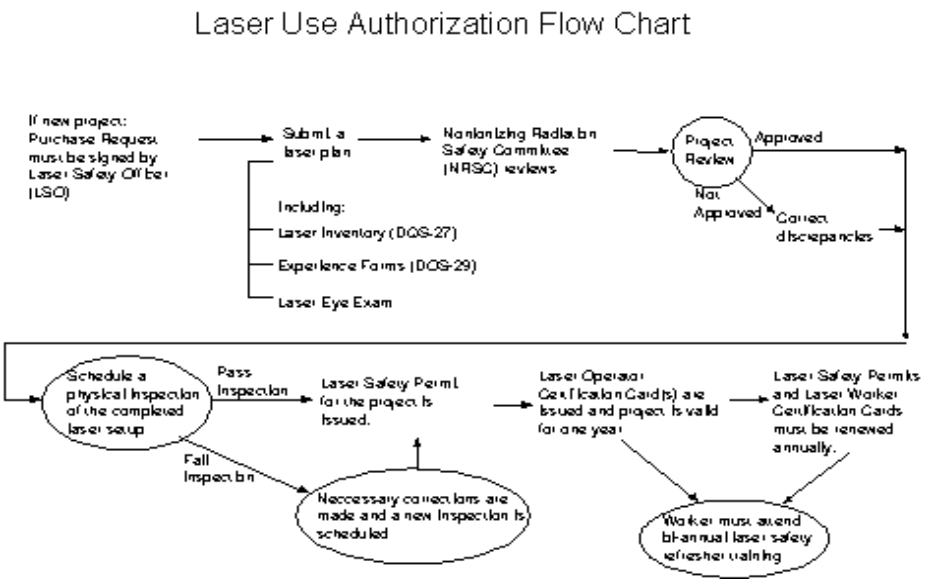
Location and date of examination (exit)

Examining Physician (signature)

ARC 72 (July 96)E Previous editions are obsolete

Copy 1 – Safety Office
Copy 2 – Health Unit
Copy 3 – Employee's Supervisor
Copy 4 – Employee

8.6.13 Appendix M: Laser Use Authorization Flowcharts



8.6.14 Appendix N: Glossary

Absorption	Transformation of radiant energy to a different form of energy by interaction with matter.
Accessible Radiation	Radiation to which it is possible for the human eye or skin to be exposed in normal usage.
Antenna	A device employed as a means for radiating or receiving electromagnetic energy.
Antenna Beam	The major lobe of the radiation pattern.
Antenna Gain (relative)	The ratio of the power gain of an antenna relative to a standard antenna. The relative gain may be in decibels or it may be numeric. The standard antenna is usually an isotropic antenna.
Aperture	An opening through which radiation can pass.
Attenuation	The decrease in the radiant flux as it passes through an absorbing or scattering medium.
Average Power (Pave)	The available transmitter power averaged over a modulation cycle (the power actually available to do the work). The average power is the peak power multiplied by the duty cycle. In continuous wave (cw) systems the average power is equal to the peak power since the duty cycle is one.
Authorized Laser User (ALU)	A person appointed by the Nonionizing Radiation Safety Committee to be responsible for laser operations in a specified area.
Average Power	The total energy imparted during exposure divided by the exposure duration.
Aversion Response	Movement of the eyelids or the head to avoid an exposure to a noxious stimulant or bright light. It can occur in 0.25 seconds, including the blink reflex time.
Beam	A collection of rays that may be parallel, divergent, or convergent.
Beam Diameter	The distance between diametrically opposed points in that cross-section of a beam where the power per unit area is 1/e (0.368) times that of the peak power per unit area.
Carcinogen	An agent potentially capable of causing cancer.
Coherent	A light beam is said to be coherent when the electric vector at any point in it is related to that at any other point by a definite, continuous function.
Collimated Beam	Effectively, a "parallel" beam of light with a very low divergence or convergence.
Continuous Wave (cw)	The output of a laser that is operated in a continuous rather than a pulsed mode. A laser that operates with a continuous output for a period of ?0.25 second is regarded as a cw laser.

Controlled Area	An area where the occupancy and activity of those within are subject to control and supervision for the purpose of protection from radiation hazards.
Cornea	The transparent, outer coat of the human eye that covers the iris and the crystalline lens. The cornea is the main refracting element of the eye.
Decibel (dB)	The unit used to express a power or voltage ratio with an arbitrarily defined reference level. The equation n (dB) = 10 log10 (P1/P2) expresses the decibel equal to 10 times the logarithm of a power ratio.
Denied Occupancy Area	Any accessible area in which the power density is 50 mW/cm2 or greater.
Diffuse Reflection	Change of the spatial distribution of a beam of radiation when it is reflected in many directions by a surface or by a medium.
Divergence	The increase in the diameter of the laser beam with distance from the exit aperture. Divergence is taken as a full angle, expressed in radians, of the beam diameter measured between those points that include laser energy or irradiance equal to 1/e of the maximum value. Divergence is sometimes referred to as beam spread.
Dummy Load	Any device introduced into an Rf or microwave system for the purpose of absorbing Rf/microwave energy.
Duty Cycle	Ratio of "on time" to total exposure duration for a repetitively pulsed system. The duty cycle is the product of the pulse duration and pulse repetition frequency.
Electromagnetic Radiation	The flow of energy consisting of orthogonally vibrating electric and magnetic fields lying transverse to the direction of propagation. X-ray, ultraviolet, visible, infrared, and radio waves occupy various portions of the electromagnetic spectrum and differ only in frequency and wavelength.
Energy	The capacity for doing work. Energy content is commonly used to characterize the output from pulsed lasers, and is generally expressed in joules (J).
Exposure	The product of an irradiance and its duration.
Far-Field Region	That region of the radiation field of an antenna where the power density variation is inversely proportional to the square of the distance from the source.
Field Strength	A measure of electric (E) or magnetic (H) field potential in an electromagnetic field, usually expressed in volts per meter (V/m) or amperes per meter (A/m).
Grounding	The process of physically providing a metallic surface or wire with a low impedance path to reference or ground potential.
Half-Power Beam Width (HPBW)	The angular width of the antenna radiation pattern between points where the power level has decreased to one-half of the maximum value.
Hertz (Hz)	The unit that expresses the frequency of a periodic oscillation in cycles per second.
Infrared Radiation	Electromagnetic radiation with wavelengths that lie within the range of 0.7 to 1.0 mm.
Intrabeam Viewing	The viewing condition whereby the eye is exposed to all or part of the laser beam where the visual angle is less than amin (see limiting angular subtense).
Ionizing Radiation	Electromagnetic radiation of a sufficient energy to directly ionize atomic or molecular systems with a single quantum event.
Iris	The circular, pigmented membrane that lies behind the cornea of the human eye. The iris is perforated by the pupil.
Isotropic Antenna	A hypothetical antenna, capable of radiating or receiving electromagnetic energy equally in all directions.
Joule (J)	A unit of energy; 1 joule = 1 watt second.
Laser	The device that produces an intense, coherent, directional beam of light by stimulating electronic or molecular transitions to lower energy levels. Laser is an acronym for light amplification by the stimulated emission of radiation.
Laser Operator	A person authorized to operate a laser, as specified on his/her Laser Worker Certification Card (ARC 314).
Laser Safety Officer (LSO)	The person, appointed by the Center director, who is responsible for ensuring safe operations of laser systems at the Center.

Laser System	An assembly of electrical, mechanical, and optical components that includes a laser.
Lasing Medium	A material emitting coherent radiation by virtue of stimulated electronic or molecular transitions to lower energy levels.
Limited Occupancy Area	Any accessible area in which the power density is greater than 10 mW/cm^2 but less than 50 mW/cm^2.
Limiting Angular Subtense	The apparent visual angle that divides amin intrabeam viewing from extended source viewing.
Maintenance	Performance of those adjustments or procedures specified in user information provided by the manufacturer with the laser or laser system that are to be performed by the user to ensure the intended performance of the product. It does not include operation or service as defined in this section.
Maximum Permissible	The maximum power density or energy density exposure (MPE) level of electromagnetic radiation that an individual may be exposed to.
Microwave Radiation	An electromagnetic wave having a wavelength of approximately 1 meter to 1 millimeter corresponding to frequencies of about 300 to 300,000 megacycles per second.
Near-Field Region	That region of the radiated field of an antenna where the power density variation is not inversely proportional to the square of the distance from the source. In this region the power density increases irregularly with range to a maximum level, then decreases approximately at a linear rate to the onset of the far-field region.
Nominal Hazard Zone (NHZ)	The nominal hazard zone describes the space within which the level of the direct, reflected, or scattered radiation during normal operation exceeds the applicable MPE. Exposure levels beyond the boundary of the NHZ are below the appropriate MPE level.
Nominal Ocular Hazard Distance (NOHD)	The distance along the axis of an unobstructed beam from the laser to the human eye beyond which the irradiation or radiant exposure during normal operation is not expected to exceed the appropriate MPE.
Operation	The performance of the laser or laser system over a full range of its intended functions. It does not include maintenance or service as defined in this section.
Optical Density (D_λ)	Logarithm to the base ten of the reciprocal of the transmittance: $D_\lambda = -\log_{10}$ (sub lambda) $t_{\&}$, where (sub lambda) is the transmittance.
Optically Pumped Laser	A laser in which the electrons are excited into an upper energy state by the absorption of light from an auxiliary light source.
Point Source	A source of radiation whose dimensions are small enough compared with the distance between source and receptor for them to be neglected in calculations.
Power	The time rate at which energy is emitted, transferred, or received; usually expressed in watts (or joules per second).
Power Density	The intensity of electromagnetic radiation present at a given point. Power density is measured in milliwatts per square centimeter (mW/cm^2).
Power, Peak	The maximum power amplitude produced in an individual pulse of energy.
prf	Abbreviation for pulse-repetition frequency. (See repetitively pulsed laser.)
Protective Housing	An enclosure that surrounds the laser or laser system that prevents access to laser radiation above the applicable MPE level. The aperture through which the useful beam is emitted is not part of the protective housing. The protective housing may enclose associated radiant energy emissions and electrical hazards associated with components and terminals.
Pulse Duration	The duration of a laser pulse; usually measured as the time interval between the half-power points on the leading and trailing edges of the pulse.
Pulsed Laser	A laser that delivers its energy in the form of a single pulse or a train of pulses. A laser with an output of < 0.25 seconds is considered a pulsed laser.
Pupil	The variable aperture in the iris through which light travels to the interior of the eye.
Q-switch	A devise for producing very short (approximately 30 ns), intense laser pulses by enhancing the storage and dumping of electronic energy in and out of the lasing medium, respectively.

Radar	A system that radiates electromagnetic waves and processes the reflection of such waves from distant objects to determine their existence and position. Radar is an acronym for radio detection and ranging.
Radian (rad)	A unit of angular measure equal to the angle subtended at the center of a circle by an arc whose length is equal to the radius of the circle. 1 radian is approximately "57.3^{o}; 2π radians=360^{o}."
Radiance, (L)	Radiant flux or power output per unit solid angle per unit area. unit: watt per square centimeter per steradian (w/m^{2}/r).
Radiant Energy (Q)	Energy emitted, transferred, or received in the form of radiation. Unit: joule (J).
Radiant Exposure (H)	Surface density of the radiant energy received. Unit: joules per square centimeter (J/m^{2}).
Radiant Flux (F)	Power emitted, transferred, or received in the form of radiation. unit: watt (W); also called radiant power.
Radiant Intensity (I)	Quotient of the radiant flux leaving the source, propagated in an element of solid angle containing the given direction, by the element of solid angle. Unit: watts per steradian (W/sr).
Reflectance	The ratio of total reflected radiant power to total incident power. Also called reflectivity.
Repetitively Pulsed Laser	A laser with multiple pulses of radiant energy occurring in sequence with a prf > 1 Hz.
Retina	The sensory membrane that receives the incident image formed by the cornea and lens of the human eye. the retina lines the inside of the eye.
Rf band	That portion of the electromagnetic spectrum that is useful for radio transmission. the current practical limits of Rf are approximately 10 MHz to 300 GHz.
Service	The performance of those procedures or adjustments described in the manufacturer's service instructions that may affect any aspect of the performance of the laser or laser system. it does not include maintenance or operation as defined in this section.
Shall	The word "shall" is to be understood as mandatory.
Should	The word "should" is to be understood as advisory.
Solid Angle	The ratio of the area on the surface of a sphere to the square of the radius of that sphere. Unit: steradians (sr).
Source	A laser or laser-illuminated reflecting surface.
Specular Reflection	A mirror-like reflection.
Standard Operating Procedure (SOP)	A document prepared by the Authorized Laser User (ALU) that describes the purpose of operations, detailed instructions on operation from startup to shutdown, and any special case operations such as alignment. The SOP shall be posted at the laser operation and a copy filed with the LSO.
Steradian (sr)	The unit of measure for a solid angle. There are 4pi steradians about any point in space.
Transmission	Passage of radiation through a medium.
Transmittance	The ratio of total transmitted radiant power to total incident radiant power.
Ultraviolet Radiation	Electromagnetic radiation with wavelengths smaller than those of visible radiation; wavelengths from 0.2 to 0.4 mm are considered to be ultraviolet.
Visible Radiation (Light)	Electromagnetic radiation that can be detected by the human eye. This term is commonly used to describe wavelengths that lie in the range from 0.4 to 0.7 μm.
Watt (W)	The unit of power or radiant flux. 1 watt="1" joule per second.
Wavelength (λ)	The distance between two successive points on a periodic wave that have the same phase. The velocity of light (3 x 10^{8} meters per second) divided by the frequency (in Hz) equals the wavelength (in meters).

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