Ames Procedural Requirements

APR 1700.1

Last Revised: February 8, 2008

COMPLIANCE IS MANDATORY

Ames Health & Safety Procedural Requirements

Chapter 8 - Laser and Microwave Safety

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8.1 Overview

This chapter provides requirements for the safe use of non-ionizing radiation devices. Non-ionizing radiation as defined in this chapter includes lasers, microwaves, and radio frequency (RF) energy.

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8.2 References

1. CFR 1040.10
2. CFR 1910.97 Non-ionizing Radiation
3. CFR 1910.133 Eye and Face Protection
4. ANSI Z 1361-2007 Safe Use of Lasers

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8.3 Responsibilities

8.3.1 Non-ionizing Radiation Safety Committee

The responsibilities for the Non-ionizing Radiation Safety Committee (NRSC) are listed in Chapter 2.

8.3.2 Laser Safety Officer (LSO)

The LSO is appointed by the Executive Safety Committee and is responsible to the NRSC for the operation of the Non-ionizing Radiation Safety Program. The LSO has the authority to suspend use of non-ionizing radiation devices if safety controls are inadequate. The LSO performs the following tasks:

1. Review non-ionizing radiation projects for safety and present the findings to the NSRC.
2. Maintain an inventory of non-ionizing radiation systems. Review the procedures and the physical set-up of the lasers used annually in order to assure that operations are in compliance with this chapter.
3. Evaluate all Class 3B and Class 4 laser experiments proposed by laser researchers for compliance with Ames Research Center policies and applicable regulations.

   NOTE: The LSO may also evaluate laser systems with classifications below 3B if optics or other means are used to focus or increase the energy of the laser.
4. Review and approve purchase requests for Class 3B and Class 4 lasers to ensure that appropriate tracking of equipment and users is accomplished.
5. Investigate mishaps that involve worker exposure to non-ionizing radiation.
6. Maintains records of all non-ionizing radiation research projects and oversee the inspections of these projects.
7. Ensure that a copy of the most current American National Standard Z136.1 is 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 ANSI Standard may be interpreted by the Ames NRSC for local applications.
8. In the absence of the LSO, the LSO will either designate a qualified alternate or the Chairperson of the NRSC to act as the LSO.

8.3.3 System Safety and Quality Assurance Division (Code QS)

The Division Chief of the System Safety and Quality Assurance Division (Code QS) will assign a representative to the Non-ionizing Radiation Safety Committee. The System Safety and Quality Assurance Representative responsibilities include:

1. Reviewing non-ionizing projects for overall system safety when these projects involve laser systems using Class 3B and Class 4 lasers and other non-ionizing radiation systems where personnel could be exposed at or near the applicable Maximum Permissible Exposure (MPE) for that radiation. This review will include a procedure review and a system safety inspection.
2. Approving by signature on the Laser Safety Permit or non-ionizing radiation project authorization when the systems safety review have been completed.

3. Approving by signature any modifications to the system.
4. Determining if other safety or engineering specialties need to be consulted, such as pressure system safety or explosive safety, and consulting with these experts in the performance of the systems safety review.

8.3.4 Authorized Laser Users (ALU)

Authorized Laser Users at Ames are certified by the Non-ionizing Radiation Safety Committee for Class 3B and Class 4 laser or laser system use. Four requirements must be met before the NRSC will consider the laser user for qualification as an ALU. Recertification is required every two years.

1. Experience. In order to be an Authorized Laser User, the researcher must have at least one year of experience using Class 3B and Class 4 lasers. The NRSC will evaluate the researcher's submitted experience form to determine if the researcher's experience meets this requirement.
2. Laser Safety Theory Training . The laser user must complete comprehensive laser safety theory training. At Ames Research Center, this theory training is delivered via a web-based course and can take from 2-4 hours. This training provides the foundation for the next two steps in the ALU certification process.
3. Laser Safety System Planning and Procedure Writing. The ALU must demonstrate an ability to apply the concepts studied in the laser safety theory course. The ALU will work closely with the LSO and NRSC to design a safe laser laboratory or research area, obtain the proper PPE, have interlocks or safety systems evaluated by appropriate engineers, and to author safe operating procedures for their laser systems. Other training and procedures may be identified as the system is designed, such as "lockout/tagout" or HAZCOM training. While these procedures are not inherently part of the ALU certification process, they may be part of the laser system certification and therefore, shall be obtained if required.
4. System Inspection and Permit Issuance. Once the procedures are acceptable to the NRSC and the system is constructed, an inspection will be conducted by the LSO and at least two members of the NRSC. The procedure and system will be inspected for overall laser safety (hazard area control, PPE, posting, interlock functionality, etc.). During this time, the prospective ALU will be required to demonstrate a thorough knowledge and practical application of laser safety principles. The LSO and NRSC representative(s) will also discuss any additional laser safety devices or practices that may be required before the Laser Safety Permit is issued. Once all of the above conditions have been met, the LSO and the NRSC are satisfied with the safety of the system, and the procedures are revised where required, a Laser Safety Permit listing the ALU will be issued in order to approve the system and complete the ALU certification process.

The responsibilities of the ALU are:

1. Being responsible for compliance with all safety regulations as outlined in the Ames Health & Safety Procedural Requirements, APR 1700.1, not simply those relating to laser safety.
2. Being responsible for the safe operation of their laser system. Deviation from safe operating procedures or actions that are not in accordance with the laser safety training or requirements is not permitted.
3. Being personally responsible for insuring that personnel using lasers under the ALU's Laser Safety Permit are properly instructed and trained to the level of responsibility authorized on that permit.
4. Providing on-the-job laser safety training to all personnel associated with the operation of the ALU's laser system. This is especially true in the case of Associate Laser Users who are working towards ALU certification. This training will reinforce the training in laser safety they have already

received and will provide practical knowledge of the safety devices, equipment and procedures of the specific laser system.

5. Being responsible for maintaining a current laser inventory, including the location of portable lasers. This shall include all research lasers in the ALU's possession, Class 1 through Class 4 research lasers inclusive.
6. Ensuring that Standard Operating Procedures (SOPs) are available at the location where the lasers will be used and with the LSO and NRSC for all Class 3B and Class 4 laser activities. These procedures must be approved by the NRSC and the LSO before being posted with the laser. The ALU will not permit the operation of a laser unless there is adequate control of laser hazards as defined by the NRSC, the SOP, and Laser Safety Training.
7. Submitting SOPs for review by the NRSC at least annually.
8. Obtaining approval of the NRSC for the entire experiment whenever any part of it deviates from the previously approved SOP.
9. Ensuring that the ALU and all lasers users shall complete the required continuing education laser safety training approved by the Ames Research Center LSO.
10. Notifying the line supervisor and the LSO immediately when the ALU believes a laser accident has occurred and sending the person potentially exposed to laser radiation to the Ames Health Unit.
11. Providing a pre-shift briefing on the laser system, the safety features, and emergency procedures to the ancillary personnel, whenever personnel other than the personnel specifically listed on the Laser Safety Permit (ancillary personnel) will be working on or near the laser system or on an associated test involving the laser system.
12. Ensuring that all personnel listed as a worker or Associate Laser User on the ALU'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 terminating employment at the Center or at the completion of a laser operation at Ames Research Center.

8.3.5 Associate Laser Users (AsLU)

Associate Laser Users (AsLU) at Ames are approved by the Non-ionizing Radiation Safety Committee to work with the Class 3B and Class 4 laser or laser systems under the direct supervision of an Authorized Laser User (ALU). In order to be authorized as an AsLU on a project, the following minimum requirements must be met:

1. Experience. The NRSC will evaluate each potential AsLU's education and research experience to ensure he/she is a good candidate for laser user. Students or researchers without a minimum of a Bachelors of Science degree in an associated science or engineering discipline will not normally be considered as an AsLU without further documentation of their qualifications to use hazardous energy and understand safety procedures and theory.
2. Laser Safety Theory Training. The laser user must complete comprehensive laser safety theory training. At Ames Research Center, this theory training is delivered via a web-based course and can take from 2-4 hours. Recertification of training is required every two years.
3. Mentor/ALU Supervisor. AsLU(s) AND FURTHER DOWN The ALU will place the AsLU(s) name in the Safe Operating Procedures and the AsLU will be listed on the Laser Safety Permit as an AsLU.

The responsibilities of the AsLU are as follows:

1. The AsLU will follow the instructions of the ALU regarding safety

2. The AsLU is responsible for reading and understanding the Safe Operating Procedures for the laser system and for following the procedures as written.
3. The AsLU is responsible for compliance with all safety regulations as outlined in the Ames Health & Safety Procedural Requirements, APR 1700.1, not simply those relating to laser safety.
4. The AsLU is responsible for the safe operation of the laser system under the direct supervision of the ALU. Deviation from safe operating procedures or actions that are not in accordance with laser safety training or requirements is not permitted.
5. The AsLU shall complete required continuing education laser safety training approved by the ARC LSO.
6. The AsLU will have laser eye exams as required by the Ames Health and Safety Manual and will wear appropriate eye protection and other required Personal Protective Equipment (PPE).
7. It is the AsLU(s) responsibility to schedule and receive an exit eye exam prior to leaving Ames or at the completion of laser operation at Ames.

8.3.6 Laser Workers and Laser System Observers

Laser Workers and Laser System Observers are personnel who will either assist in the system design, construction, alignment, or operation or may need access to the laser hazard area to observe a test or study. These personnel will not be authorized to operate a laser or laser system. Laser Workers and Laser System Observers at Ames are approved by the Non-ionizing Radiation Safety Committee to work with Class 3B and Class 4 laser or laser systems under the direct supervision of an Authorized Laser User (ALU). To be authorized as a Laser Worker or Laser System Observer on a project, the following minimum requirements must be met:

1. Laser Safety Theory Training. The laser user must complete comprehensive laser safety theory training. At Ames Research Center, this theory training is delivered via a web-based course and can take from 2-4 hours. Recertification of training is required every two years.
2. ALU Supervisor. Laser Workers and Laser System Observers shall always be supervised by an ALU. Entry into the laser hazard area will only be allowed when the ALU is present and has approved the entry. The ALU will place the Laser Worker or Laser System Observers' name in the Safe Operating Procedures and Laser Worker/Laser System Observer will be listed on the Laser Safety Permit as a Laser Worker or Laser System Observer.

Laser Workers and Laser System Observers have the following responsibilities:

1. Following the instructions of the ALU regarding safety procedures.
2. Being responsible for reading and understanding the Safe Operating Procedures for the laser system and for following the procedures as written.
3. Being responsible for compliance with all safety regulations as outlined in the Ames Health & Safety Procedural Requirements, APR 1700.1, not simply those related to laser safety.
4. Being responsible for following the safe operating procedures for the laser and laser system on which they are not working. Deviation from safe operating procedures or actions that are not in accordance with laser safety training or requirements is not permitted.
5. Completing required continuing education laser safety training approved by the ARC LSO as long as they are listed on a Laser Safety Permit.
6. Scheduling and receiving laser eye exams as required by the Ames Health and Safety Manual.
7. Wearing appropriate eye protection and other required Personnel Protective Equipment (PPE).

8. Scheduling and receiving an exit eye exam prior to leaving Ames or after completing laser operations at Ames.

8.3.7 Ancillary Non-Laser Personnel

Ancillary personnel are those workers who are not authorized to enter the laser controlled area but who may be performing work near or around the controlled area. It is important that they are aware of the hazards and understand the posting and boundaries of the controlled area. Ancillary personnel must receive a pre-job briefing from the ALU on applicable laser hazards. They are required to obey and comply with the ALU(s) directions and orders concerning laser safety and the laser system. Work near or around a laser controlled area shall not be conducted without a safety briefing from the Authorized Laser User for the laser or laser system.

8.3.8 Authorized Users of Other Sources of Non-ionizing Radiation

The use of any non-ionizing radiation source that may emit radiation above the applicable Maximum Permissible Limit (MPE) for personnel exposure will only be allowed with the authorization of the Non-ionizing Radiation Safety Committee. For non-ionizing radiation sources, such as microwave, Rf, or infrared generators, the hazard and controls will be evaluated by the NRSC prior to authorizing the user to use the source. The user of the non-ionizing radiation source shall provide the Laser Safety Officer with a minimum of standard operating procedures or applicable sections of the manufacturer (s) manuals, wavelength or frequency of the source, the power of the unit, dish or emitter dimensions, the experience level of the user, and a description of the proposed use of the source. The NRSC and the Laser Safety Officer will approve the use of the source once they are confident it will be used safely and no personnel will be exposed to levels of non-ionizing radiation above the applicable MPE. Because there are many sources of non-ionizing radiation and the means of control for most are unique, the user shall contact the Ames Laser Safety Officer for consultation and for requirements for authorization for the specific non-ionizing radiation source.

The Authorized User of microwave/Rf equipment is personally responsible for compliance with the applicable microwave/Rf standard as specified by the Laser Safety Officer and Ames regulations on all operations. Operations are authorized by the NRSC. The responsibilities of a non-ionizing radiation source user other than lasers are similar to those specified for Authorized Laser Users:

1. The AU is responsible for compliance with all safety regulations as outlined in the Ames Health & Safety Procedural Requirements, APR 1700.1, not simply those relating to non-ionizing radiation safety.
2. Preparation of an initial Safety Review document for new projects or modifications to existing facilities.
3. Providing safety instructions to personnel using equipment under his or her direction.
4. Prohibiting the use of the equipment unless there is adequate control of hazards, including warning signs and interlocks as necessary.
5. Notifying the Laser 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 within 24 hours.
6. Adopting practices that will not intentionally expose an individual to microwave/Rf radiation in excess of the Maximum Permissible Exposure (MPE) limits.

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8.4 Laser Safety

Hazards associated with laser use are described in Appendix B. Required actions to control these hazards are described in this section.

8.4.1 Laser Acquisition

NASA Ames civil servant and contractor personnel are required to notify the LSO of any decision to purchase, fabricate, or otherwise acquire either Class 3B or Class 4 lasers. The LSO will review with the user the hazards of the proposed operation and make recommendations regarding the specific safety requirements that pertain to the proposed use, including requirements for SOP(s), laser control areas, training, and personnel protection equipment. Frequently, lasers are embedded in laser products or systems with a lower hazard rating. For example, laser printers, CD players, and laser scanning confocal microscopes are Class 1 products, but they contain Class 3B or Class 4 lasers. When the laser system is used as intended, the controls for the system(s) class apply. When the system is opened (e.g., for service or alignment) and the embedded laser beam is accessible, a temporary control area must be established. The controls for the temporary control area must be based on the classification of the embedded laser. The user and LSO must determine adequate controls.

Confirmation of a system classification is the responsibility of the LSO, and therefore, necessitates the registering of the system. An abbreviated SOP may be required as in the case of such commercially available enclosed laser systems as a laser scanning confocal microscope.

8.4.2 Laser Classification

Laser safety standards are derived from government-mandated regulations and voluntary standards. Safety rules governing the manufacture of lasers are established by the Federal Government. Laser products manufactured after August 2, 1976 must conform to performance standards established by the Food and Drug Administration (FDA) (21 CFR 1040.10). The standard requires that lasers are properly classified by the manufacturers. Thus, for most lasers measurements or calculations to determine the hazard classification are unnecessary. In addition, the standard establishes certain engineering requirements for each class and requires warning labels that state maximum output.

Lasers are classified according to the ability of the primary or reflected beam to injure the eye or skin. The appropriate class is determined from the wavelength, power output, and duration of pulse (if pulsed). Classification is based on the maximum accessible output power. There are six major laser classes, with Class 1 representing the least hazardous. All lasers, except Class 1, must be labeled with the appropriate hazard classification.

Class 1 Laser System

Class 1 lasers do not emit harmful levels of radiation during normal operation and are, therefore, exempt from control measures. As a matter of good practice, unnecessary exposure to Class 1 laser light should be avoided.

Class 1 lasers can be used without restriction in the manner intended by the manufacturer and without special training or qualification of operating personnel. These personnel, however, should not be exposed to laser light unnecessarily.

Class 1M lasers are 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 exempt from any control measures other than to prevent potentially hazardous optically aided viewing; and is exempt from other forms of surveillance.

Class 2 Lasers

Class 2 lasers emit accessible laser light in the visible region and are capable of causing eye damage through chronic exposure. In general, the human eye will blink within 0.25 second when exposed to Class 2 laser light. This blink reflex provides adequate protection. It is possible, however, to overcome the blink reflex and to stare into Class 2 laser long enough to cause damage to the eye. The upper power limit for Class 2 lasers is 1 milliwatt (mW). Class 2 lasers are commonly utilized during alignment applications.

Class 2 lasers can be used without restriction in the manner intended by the manufacturers and without special training of operating personnel. Personnel, however, should not be exposed to laser light unnecessarily.

Class 2M lasers emit in the visible portion of the spectrum (0.4 to 0.7 m) and eye protection is normally afforded by the aversion response for unaided viewing. However, Class 2M is potentially hazardous if viewed with certain optical aids.

Class 3 Lasers

Class 3 lasers may be hazardous under direct and specular reflection viewing conditions, but is normally not a diffuse reflection or fire hazard

There are two subclasses:

- A Class 3R laser system is potentially 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. The laser will not pose either a fire hazard or diffuse-reflection hazard.
- A Class 3B laser system may be hazardous under direct and specular reflection viewing conditions, but is normally not diffuse reflection or fire hazard.

Class 4 Lasers

Class 4 lasers include all lasers with power levels greater than 500 mW CW or greater than 0.03J for a pulsed system. They pose eye hazards, skin hazards, and fire hazards. Viewing of the beam and of specular reflections or exposure to diffuse reflections can cause eye and skin injuries. Class 4 lasers may also produce laser-generated air contaminants (LGAC) and hazardous plasma radiation. All of the control measures explained in this document must be implemented.

All requirements of the NASA Ames Laser Safety Program apply to Class 3B and Class 4 lasers.

Requirements by Laser Classification

Class	Procedural & Administrative Controls	Training	Medical Surveillance	LSO
1	Not Required	Not Required	Not Required	Not Required
1M	Required	Application Dependent (2)	Application Dependent (2)	Application Dependent (2)
2	Not Required (1)	Not Required (1)	Not Required	Not Required
2M	Required	Application Dependent (2)	Application Dependent (2)	Application Dependent (2)
3R	Not Required (1)	Not Required (1)	Not Required	Not Required (1)
3B	Required	Required	Require d	Required
4	Required	Required	Required	Required

Note: During maintenance and service the classification associated with the maximum level of accessible laser radiation shall be used to determine the applicable control measures.

1) *Not required except for conditions of intentional intrabeam exposure applications.*
2) *Certain uses of Class 1M or 2M lasers or laser systems that exceed Class 1 or Class 2 because they do not satisfy Measurement Condition 1 (optical viewing) may require hazard evaluation and/or man ufacturer's information.*

Medical Surveillance

All personnel who work with Class 3B and 4 lasers or who are permitted by the LSO 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.

Workers and Laser System Observers are subject to the following baseline exam (Ancillary Non-Laser Personnel may request the baseline exam and the Laser Safety Officer and NRSC will determine if this exam is appropriate). This exam will normally be scheduled through the Ames Health Unit.

1. Ocular History. If the ocular history shows no problems and visual acuity is found to be 20/20 (6/6 in each eyed for far, and Jaeger 1 + for near) with corrections (whether worn or not) and Amsler Grid Test and Color Vision responses are normal, no further examination is required.
2. Ocular Fundas. Individuals whose ocular function is not normal according to the above testing will undergo examination of the ocular fundas with an ophthalmoscope or appropriate fundas lens at slit lamp. The points to be covered are the following: the presence or absence of opacities in the media; the sharpness of outline of the optic disc; the color of the optic disc; the depth of the physiological cup, if present; the ratio of the size of the retinal veins to that of the retinal arteries, the presence or absence of a well defined macula and the presence or absence of a foveal reflex; and any retinal pathology that can be seen with an ophthalmoscope (hyperpigmentation, de-pigmentation, retinal degeneration, exudates, as well as any induced pathology associated with changes in macular function). Even small deviations from normal should be described and carefully localized. Dilation of the pupil is required.
3. Skin Examination. Not required for pre-placement examinations of laser workers; however, it is suggested for employees with history of photosensitivity or working with ultraviolet lasers. Any previous dermatological abnormalities and family history are reviewed. Any current complaints concerned with the skin are noted as well as the history of medication usage, particularly concentrating on those drugs that are potentially photosensitizing.

Further examination should be based on the type of laser radiation, above the appropriate MPE levels, present in the individual's work environment.

Medical Evaluation Following Suspected or Known Laser Injury. Any employee with a suspected eye injury shall be referred to an ophthalmologist. Employees with skin injuries shall be seen by a physician. Injured or potentially injured employees will report to the Health Unit if the injury occurs during normal working hours. Injured or potentially injured employees will call Dispatch for assistance after hours. In either case, the on-call Health Unit doctor and the Laser Safety Officer will be notified of the injury as soon as possible.

Workers and Laser System Observers are subject to the following baseline exam (Ancillary Non-Laser Personnel may request the baseline exam and the Laser Safety Officer and NRSC will determine if this exam is appropriate). This exam will normally be scheduled through the Ames Health Unit.

1. Ocular History: If the ocular history shows no problems and visual acuity is found to be 20/20 (6/6 in each eye for far, and Jaeger 1 + for near) with corrections (whether or not) and Amsler Grid Test and Color Vision responses are normal, no further examination is required.
2. Ocular Fundas: Individuals whose ocular function is not normal according to the above testing will undergo examination of the ocular fundas with an ophthalmoscope or appropriate fundas lens at slit lamp. The points to be covered are the following: the presence or absence of opacities in the media; the sharpness of outline of the optic disc; the color of the optic disc; the depth of the physiological cup, if present, the radio of the size of the retinal veins to that of the rentinal arteries, the presence of a well defined macula and the presence or absence of a foveal reflex; and any retinal pathology that can be seen with an ophthalmoscope (hyperpigmentation, de-pigmentation, retinal degeneration, exudates, as well as any induced patho9logy associated with changes in macular function). Even small deviations from normal should be described and carefully localized. Dilation of the pupil is required.
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concentrating on those drugs that are potentially photosensitizing.

Further examination should be based on the type of laser radiation above the appropriate MPE levels present in the individual's work environment.

Medical Evaluation Following Suspected or Known Laser Injury. Any employee with a suspected eye injury shall be referred to an ophthalmologist. Employees with skin injuries shall be seen by a physician. Injured or potentially injured employees will report to the Health Unit if the injury occurs during normal working hours. Injured or potentially injured employees will call Dispatch for assistance after hours. In either case, the on-call Health Unit doctor and the Laser Safety Officer will be notified of the injury as soon as possible.

Normal working hours: Health Unit at [redacted] and the Laser Safety Officer at [redacted]

After hours/off shift: For Medical Assistance or to reach the Laser Safety Officer, call Dispatch at [redacted] [redacted] or [redacted]

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8.5 Laser Safety Controls

8.5.1 Class 3B and Class 4 Control Areas

Class 3B and Class 4 lasers may be operated only in the designated laser control areas approved by LSO and the NRSC. The purpose of laser control areas is to confine laser hazards to well-defined spaces that are under the control of the authorized laser user to prevent injury to those visiting and working near the control area. All personnel who require entry into a Class 3B and Class 4 laser controlled area during laser operations, maintenance, or servicing shall be appropriately trained as described in sections 8.3.4 through and including 8.3.8 of this chapter. Class 3B and Class 4 laser control areas must meet the following administrative and operational control requirements.

Nominal Hazard Zone (NHZ)

In situations requiring open laser beams it is necessary to define an area, within the Control Area, of potentially hazardous laser radiation. This area is referred to as the Nominal Hazard Zone (NHZ), which is defined as a space within which the level of direct, scattered, or reflected laser radiation exceeds the Maximum Permissible Exposure (MPE). The purpose of a NHZ is to define the area in which control measures (e.g., laser eyewear) are required. The LSO and the ALU will determine the NHZ. The NHZ may in some situations comprise the entire Control Area.

Posting

The Control Area must be posted with appropriate warning signs that indicate the nature of the hazard. The wording on the signs will be specified by the LSO and conform to the ANSI Z136.1 guidelines. Such signs shall be posted at all entrances to the laser control area. Examples of proper signage can be found in ANSI 2136.1

Authorization and Path to Laser Use at Ames

Only personnel who have been authorized by the NRSC may operate the laser. This approval will be specific to each laser and each laser system configuration. The actions required for approval of laser operating at NASA-Ames Research Center are found in Sec. 8.2.1 Appendix A of this Chapter.

Beam Stops

All laser beams must be terminated at the end of their useful paths by a material that is minimally reflective at the laser wavelength and fire resistant (beam stop). Beam stops will also be placed at the laser output to prevent inadvertent harmful laser radiation being emitted when the laser is not meant to be operated. Examples of this would be when personnel enter down range of the laser to adjust models or when an experiment is temporarily stopped and the laser is secured. Emergency safety systems and interlocks will not be used as the primary means of protection from injury.

Lockout Tagout Procedures (LOTO)

LOTO is required whenever servicing, maintenance, or modification is being performed on equipment in which the unexpected energization or startup of the equipment, or the release of stored energy, could cause injury to people or damage to equipment. All sources of hazardous energy must be shut off and secured. LOTO must b e performed by each person who works on the equipment. Refer to Chapter 31 of this manual for LOTO procedures and regulations.

Laser Out of Service Tag (DOS 30)

When a laser is taken out of service or is not covered under an active Laser Safety Permit, the ALU shall request a “Laser Out of Service” tag be issued. A serial number will be issued to the ALU and noted on the tag. The tag will be hung on the laser by the ALU denoting it is inactive not to be used. This tag is an administrative control only and is not to be used in lieu of LOTO procedures if required by Chapter 31 of this manual.

Eye Protection

Lasers should be mounted so that the beam path is not at eye level for standing or seated personnel (i.e., above 6.5 feet or below 3 feet). Laser protective eyewear of adequate optical density and threshold limit for the beam(s) under manipulation must be provided to all present individuals and worn at any point where the laser exposure could theoretically exceed the MPE. Procedures and practices must ensure that optical systems and power levels are not adjusted upstream during critical open beam operations, such as beam alignment. It is the responsibility of the Authorized Laser User to obtain appropriate laser protective eyewear. For assistance in selecting laser eye protection, contact the LSO. The LSO can assist the user in determining the proper parameters of such eyewear, and can provide contact numbers for vendors. Laser eye protective should be inspected periodically to ensure that it is in good condition.

Light Containment

Laser light levels in excess of the MPE must not pass the boundaries of the control area. All windows, doorways, open portals, and other openings through which light might escape from a laser control area must be covered or shielded in such a manner as to preclude the transmission of laser light. Special rules apply for outdoor use and laser control areas that do not provide complete containment. Contact the LSO for details.

Electrical Safety

High voltage sources and terminals must be enclosed. Capacitors must have bleeder resistors, discharge devices, or automatic shorting devices. Electrical circuits should be evaluated with respect to fire hazards.

Rapid Egresses and Emergency Access

There must be provisions for rapid egress from a laser control area under all normal and emergency conditions. Any control area interlock system musts not interfere with emergency egress. In addition, access control measures must not interfere with the ability of emergency response personnel (fire, paramedical, police) to enter the laser control area in the event operating personnel become injured or incapacitated.

Entryway Controls

Procedural area or entryway controls must be in place to prevent inadvertent exposure to the active laser beam.

Non-defeatable safety latches, entryway or area interlocks (e.g. electrical switches, pressure sensitive floor mats, infrared, or sonic detectors) shall be used to deactivate the laser or reduce the output to levels at or below the appropriate MPE in the event of unexpected entry into the laser Control Area.

All authorized personnel shall be adequately trained and adequate personal protective equipment shall be provided upon entry.

A door, blocking barrier, screen, curtains, etc. shall be used to block, screen, or attenuate the laser radiation at the entryway.

At the entryway there shall be a visible lighted laser warning sign or audible signal indicating that the laser is energized and operating.

8.5.2 Temporary Laser Control Areas

Temporary laser control areas can be created for the servicing and alignment of embedded lasers, enclosed lasers, and in special cases where permanent laser control areas cannot be provided. They are subject to the normal SOP approval process or vendor safety procedures if adequate.

8.5.3 Substitution of Alternate Control Measures

Upon documentation review by the LSO and the NRSC, the engineering control measures recommended by ANZI Z136.1 for Class 3B and Class 4 lasers or laser systems may be replaced by administrative or other alternate engineering controls that provide equivalent protection. Approvals of these controls are subject to the same review procedure as described in this chapter.

8.5.4 Changes to Control Areas or Control Measures

Once a control area or control measure is approved by the NRSC all but minor changes to that control area or measure must be approved by the NRSC. An example of a minor change would be to add a curtain or move a sign or beacon in such a manner as to not decrease the functionality of the barrier. Movement of lasers, reconfiguration of interlocks, increasing or decreasing the size of the control zone, or any other similar modification, requires NRSC approval. The LSO will be contacted to obtain this approval. In most cases a new system inspection will be required.

8.5.5 Outdoor Use of Lasers

Laser use outdoors requires additional controls because the hazard zone can be extended for much greater distances. This results in hazards to aircraft, satellites, and personnel, possibly beyond the normal sight of the ALU. Contact the LSO directly for additional requirements associated with any outdoor use of lasers. Outdoor laser experiments may take as long as one year to approve, due to the requirement for additional organizational approval (i.e., FAA, Air Force Space Command, etc.)

8.5.6 Earthquake Bracing

In California, natural disaster conditions such as earthquake need to be considered in the designs and use of equipment. Examples would be fastening electronic racks to the floor or walls, and having at least two locking wheels on rolling racks and tying down computer monitors. When possible, bolt down heavy laser equipment. One should be aware of tall objects (bookcases, optical storage racks) that if tipped over would block access into or out of a work space.

8.5.7 Area Illumination

Adequate lighting is a standard recommendation. If low light levels are required, have luminescent strips or arrows to show the way to exits and emergency equipment.

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8.6 Microwave/RF Radiation Safety

8.6.1 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.

8.6.2 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).

8.6.3 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 procedure (SOPs).Standard communication dish antennas that are permanently mounted will be reviewed only when modification to the antenna or the antenna surroundings may cause a new hazard to personnel. Contact the Laser Safety Officer (Non-ionizing Radiation Safety Officer) for an evaluation if modifying an existing antenna or if situations exist that will place personnel near the permanently mounted antenna.

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Appendix A: Path to Operate a Laser or Laser System at NASA Ames Research Center

1. All personnel complete Laser Safety Training
   (Web Based: http://q.arc.nasa.gov/qh/classes/physics/il.php)
2. All personnel read Chapter 8 of the Ames Health and Safety Procedural Requirements Manual.
3. Authorized Laser User submit a Laser Plan.

   a. Laser Inventory

      i. Manufacturer, Model, Serial Number(s).
      ii. Max Power (CW) or Energy (pulse)
      iii. Type (e.g. Ng:YAG, Argon, etc.)
      iv. Wavelength
      v. Class (1, 1M, 2, 2M, 3R, 3B, 4)
      vi. Pulse Width
      vii. Pulse Rate

viii. Beam Diameter
ix. Divergence

b. Experience Forms (DQS-29)
c. Laser Eye Exam
d. Standard Operating Procedures

i. Alignment Procedures
ii. Normal Operating Procedures
iii. Specific Laser Safety Procedures (interlocks, safety glasses, posting)
iv. Diagram of system showing layout, posting, interlocks, etc.

4. Non-Ionizing Radiation Safety Committee Reviews and Approves Procedure
5. Laser Safety Officer/Committee Walk-Through of Laser Set-Up.
6. Letter and Laser Safety Permit Issued Approving Laser Operations
7. Annually Renew Project.
8. Bi-Annually Renew Training.

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Appendix B: Laser Hazards

Biological Effects and Target Organs

Eyes

The eye is extremely vulnerable to injury if exposed to the beams from most types of lasers. The type of injury depends upon the intensity of light, its wavelength, and the tissue being exposed. Damage results from either temperature or photochemical effects. Acute exposure may result in corneal or retinal burns. Cataract formation or damage to the retina may result from chronic exposure to laser light. Retinal damage is of particular concern from exposure to wavelengths in the visible and near infrared region. Most sources of incoherent light can be viewed safely because the light reaching the eye is only a small portion of the total output and the energy is spread over the entire retina. Laser radiation, however, is composed of coherent light. The beam can pass through the pupil and focus on a very small spot on the retina, depositing all its energy on this area. Only visible and near infrared radiation is focused on the retina. Damage to the retina may result in limited or total blindness if the optic nerve is injured. Injury maybe irreversible and there may be no pain or discomfort from the exposure In addition to heat damage, some very high powered, short-pulsed lasers such as the carbon dioxide and the Nd YAG mode-locked laser can mechanically disrupt the retina and cause the eye to hemorrhage.

Skin

Damage to the skin is also possible from exposure to laser beams. Acute exposure may cause injuries ranging from mild reddening to blistering and charring. Skin cancers may result from chronic exposure to ultraviolet light. The extent and type of damage depends on the amount of energy deposited and the wavelength of the light. Unlike injury to the eye, acute damage to the skin is usually repairable.

Biological Effects - Wavelength Effect

Ultraviolet Radiation (200-400 nanometers)

Ultraviolet light in the 200 - 315 nn range is absorbed by the cornea and may cause photokeratitis (corneal inflammation). Unlike the skin, repeated exposure of the cornea to ultraviolet light does not result in a protective mechanism. Near ultraviolet light between 315 - 400 nm is absorbed largely in the lens and may cause cataracts. Wavelengths less than 400 nm do not pose a hazard to the retina.

Exposure to the skin from lasers that emit in the UV region may cause a photochemical reaction resulting in reddening, aging, and possibly skin cancer.

Photochemical Damage

Laser light having wavelength below 400 nm is absorbed by the lens and cornea and does not reach the retina. Depending on the level of exposure, this may cause immediate thermal burns or the development of cataracts over a period of years.

The light can be laser output, ultraviolet (UV) from the pump light, or blue light from a target interaction. The effect is cumulative over a period of days. The ANSI standard is designed to account only for exposure to the laser light. If UV light from a pump light or blue light from a target interaction is emitted, additional precautions must be taken.

Examples of lasers operating in the ultraviolet region include the neodymium YAG-Quadrupled (QSW & CW) and the Ruby (doubled) laser.

Other Eye Hazards

The cornea and the conjunctiva tissue surrounding the eye can also be damaged by exposure to laser light. Damage to the cornea and conjunctiva tissue usually occurs at greater power levels than damage to the retina; therefore, these issues only become a concern for those wavelengths that do not penetrate to the retina (i.e., UV and FIR radiation).

Visible and Near-Infrared Radiation (400 – 1,400 nanometers)

Exposure to laser beams in the visible (300 - 700 nm) and near-infrared (700 - 1400 nm) regions of the spectrum may damage the retina. Laser beams in this region are readily transmitted by the eye and focused by the lens to produce an intense concentration of light energy on the retina. The incident exposure on the cornea can be concentrated by a factor of approximately 100,000 times at the retina due to this focusing effect. This energy is converted to heat and may cause a retinal burn resulting in visual loss or even blindness if the optic nerve is injured. Even low energy laser beams, if concentrated by a factor of 100,000 can cause damage to the eye. For this reason wavelengths in the 400 - 1,400 nm range are termed the ocular hazard region. Retinal injury from this wavelength can result in either thermal burns or acoustic damage.

Thermal Burn (Retina)

Normal focusing by the eye results in an irradiance amplification of approximately 10,000; therefore, a 1 mW/cm2 beam entering the eye will result in a 100 W/cm2 exposure at the retina. The most likely effect of intercepting a laser beam of sufficient irradiance with the eye is a thermal burn that destroys the retinal tissue. The ANSI Maximum Permissible Exposure (MPE) values are set well below the threshold level for thermal burns.

Acoustic Damage (Retina)

Laser pulses of duration less than 10 microseconds induce a shock wave in the retinal tissue that causes a rupture of the tissue. This damage is permanent, as with the retinal burn. Acoustic damage usually affects a greater area of the retina, and the threshold energy for this effect is substantially lower. The ANSI MPE values are reduced for short laser pulses to protect against this effect.

Exposure to the skin from laser beams in the visible and infrared regions may cause photosensitive reactions, skin burns and excessive dry skin. Lasers operating in the visible region of the spectrum include the ruby, neodymium: YAG (doubled); helium-cadmium, helium-neon, argon, and krypton. Lasers operating in the near-infrared region include the neodymium, gallium arsenide, and helium-neon.

Middle and Far-Infrared Radiation (1,400 -10,000 nanometers)

Laser beams in the middle and far-infrared regions produce injury primarily to the cornea and to a lesser extent, the lens. Damage is usually from heating effects, although pulsed lasers such as the carbon dioxide laser may cause injury from thermomechanical effects. Virtually no light reaches the retina beyond 1,400 nm. Middle infrared radiation between 1,400 nm and 3,000 nm may penetrate deep into the lens causing cataracts. Far-infrared radiation in the 3,000 - 10,000 nm range is absorbed by the cornea and may cause corneal burns and loss of vision.

The major danger to the skin from lasers operating in this region is burn damage.

The cornea and the conjunctive tissue surrounding the eye can also be damaged by exposure to laser light. Damage to the cornea, therefore, these issues only become a concern for those wavelengths that do not penetrate to the retina (i.e., UV and FIR radiation).

Secondary Laser Hazards

Electrical Hazards

Lethal electrical hazards may be present, especially around high power laser systems. To date, the most common cause of death associated with laser system use is electrocution. Continuous wave lasers use direct current or radiofrequency power supplies and pulsed lasers employ large capacitor banks for electrical storage. Lasers and associated electrical equipment must be designed, constructed, installed and maintained in accordance with the latest revision of the National Electrical Code (NEC), the Occupational Health and Safety Administration (OSHA) standards, and other applicable industry standards including the American National Standards Institute (ANSI) and the Institute of Electrical and Electronics Engineers, Inc. (IEEE).

Electrical circuits greater than 42.5 volts are considered hazardous unless limited to less than 0.5 mA. To reduce electrical hazards, high voltage sources and terminals must be enclosed unless the work area is restricted to qualified persons only. Capacitors must be equipped with bleeder restrictors, discharge devices, or automatic shorting devices.

Laser Generated Air Contaminants (LGACs)

Vaporized target materials, toxic gases, vapors and fumes may be present in a laser area. Ozone is produced around flash lamps and concentrations of ozone can build up with high repetition rate lasers. Asbestos fibers may be released from the firebrick used as backstops for carbon dioxide lasers. The increasing use of chemical lasers may introduce chemical hazards that are more dangerous than the laser radiation. For example, fluorides used in a fluoride laser are highly toxic and demand immediate emergency measures upon contact. He-Cd lasers may contaminate the laboratory with toxic cadmium vapors if the exhaust gases are not vented to the outside. The dyes that are the active medium of tunable lasers are often very toxic and may cause acute or chronic skin problems. Some dyes may be carcinogenic.

Flammable Hazards

Flammable solvents, gases, and combustible materials may be ignited by a Class 4 laser beam. Laser beams should be terminated by a non-combustible material such as a brick or beam stop/dump. Combustible solvents or materials should be stored in proper containers and shielded from the laser beam or electrical sparks. Lasers and laser facilities should be constructed and operated to eliminate or reduce any fire hazard. Unnecessary combustible materials should be removed in order to minimize fire hazards. Laser laboratories should contain an appropriate fire extinguisher.

Laser Dyes

The organic dyes used in some laser systems are known to be carcinogens, mutagens, or teratogens. Proper laboratory safety protocols must be used when preparing, storing, handling, using, and disposing of laser dyes.

Cryogenics

Cryogenic liquids (especially liquid nitrogen) may be used to cool the laser crystal and associated receiving and transmitting equipment. These liquid gases are capable of producing skin burns and may replace the oxygen in small unventilated rooms. The storage and handling of cryogenic liquids must be performed in a safe manner.

Noise

Noise levels in laser laboratories can exceed safe limits because of high voltage capacitor discharges. Hearing protection may be required.

X-Rays

X-ray production is possible when voltages exceed 15 kV. Although most laser systems uses voltages less than 8 kV, some research models may operate above 20 kV. Laser systems capable of producing ionizing radiation must be surveyed by the Radiation Safety Officer to insure that x-ray levels are within legal limits.

Ultraviolet Radiation

Although laser radiation presents the chief hazard, it may not be the only optical hazard. Laser discharge tubes and pumping tubes may emit hazardous levels of ultraviolet radiation and should be suitably shielded. Particular care should be used with quartz tubes. Most lasers now use heat-resistant glass discharge tubes which are opaque in the UV-B (280 - 315 nm) and UV-C (100 - 289 nm) spectrum.

Ergonomics

There may be ergonomic hazards associated with the operation, maintenance, or service of the laser system. These ergonomic hazards such as awkward posture could cause injury if not addressed.

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

Table 1 Maximum Permissible Exposure for Controlled Environments

Part A: Electromagnetic Fields[1]

1 Frequency Range (MHz)	2 Electric Field Strength (E) (V/m)	3 Magnetic Field Strength(H) (A/m)	4 Power Density/ E-Field, H field (mW/cm^2)	5 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 area equivalent 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.

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Appendix D: Microwave/Rf limts (uncontrolled environment)

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/cm²)	(minutes)	
0.003 - 0.1	614	163	(100, 1 000 000) [2]	6	6
0.1 - 1.34	614	163/f	(100, 10 000/f²) [2]	6	6
1.34 - 3.0	823.8/f	163/f	(180/f²,10 000/f²) [2]	f²/0.3	6
3.0 - 30	823.8/f	16.3/f	(180/f²,10 000/f²) [2]	30	6
30 - 100	27.5	$158.3/f^{1.668}$	$(0.2, 940\ 000/f^{3.336})$ [2]	30	$0.0636f^{1.337}$
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.

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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, usually that portion of the

emitted radiation beam within the beam diameter circle.

Antenna Gain (relative): The ratio of the power gain of 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.

Aperature: 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.

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 is1/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 hat at any other point by a definite, continuous function.

Collimated Beam: Effectively, a "parallel" beam of light with a very low divergence ore convergence.

Continuous Wave (cw): The output of a laser that is operated in a continuous rather than a pulsed mode. A laser that operated 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 arbitrary defined reference level. The equation n (dB0 = 10 log10 (P1/P2) express the decibel equal to 10 times the logarithm of a power ratio.

Diffuse Reflection: Reflection in which incident radiation at a single angle of incidence is redirected in many directions.

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: The flow of energy consisting of orthogonally vibrating

Radiation: 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 fidder 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/cm2 but less than 50 mW/cm2.

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 (Dλ): Logarithm to the base ten of the reciprocal of the transmittance at a particular wavelength.

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/cm2).

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 degrees; 2 PI radians=360 degrees.

Radiance, (L): Radiant flux or power output per unit solid angle per unit area. unit: watt per square centimeter per steradian (w/m2/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/m2).

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:	The distance between two successive points on a periodic wave that have the same phase. The velocity of light (3 x 108 meters per second) divided by the frequency (in Hz) equals the wavelength (in meters).

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END OF DOCUMENT

THIS DOCUMENT IS UNCONTROLED WHEN PRINTED