SFU LASER SAFETY MANUAL

Record of changes

Date	Revised by	Revision
2020.07.08	n/a	Original version
2022.01.19	Monica Szczepina	Medical examination requirements and laser disposal procedures included

Contents

1. SFU Laser safety administration and oversight

1.1 Introduction

A laser safety program is in place at SFU and is administered by the University Radiation Safety Committee (URSC) and the Laser Safety Officer (LSO). The purpose of such a program is to monitor teaching and research facility design, procedures, equipment, and to implement and enforce the policies, regulations and procedures for the control and safe use of lasers and laser systems.

The SFU Laser Safety Program, SFU's Radiation Safety Policy (R 20.05) and this Laser Safety Manual have been developed in compliance with WorkSafeBC's Occupational Health and Safety Regulation, the American National Standard for Safe Use of Lasers (ANSI Z136.1), and all related regulations and standards. The ANSI Z136.1 standards are the foundation of evaluating laser-related occupational safety.

Users of lasers and lasers systems have a responsibility to protect themselves and others from the hazards arising from their use of these devices. This document strives to provide information for students, staff and faculty to safely work with lasers by:

- identifying potential hazards associated with lasers, laser systems, and laser operations;
- prescribing a suitable means of evaluating and controlling these hazards; and
- outlining the procedures, responsibilities and expectations that need to be met in accordance with all relevant acts, regulations and standards.

1.2 Scope

This policy and program applies to all departments, staff, students, volunteers, and visitors at Simon Fraser University working with laser generating equipment and devices from class 3B and class 4.

1.3 SFU Laser safety program framework

The Laser Safety Program ensures the safety of the SFU community in the effective control of laser hazards. The basic elements of the control program are:

- registration of all class 3B and class 4 laser/laser systems (through SFU's Hazard Inventory System: labhazindex.its.sfu.ca);
- inspections of class 3B and class 4 laser/laser systems;
- requirement for training and education of laser workers through:
    - General laser safety orientation – EHS
    - Laboratory specific training – Principal Investigator
- reporting accidents/incidents;
- medical surveillance;
- requirement for personal protective equipment;
- requirement for engineering controls; and
- requirement for administrative and procedural controls.

2. Roles and responsibilities

2.1 Principal Investigators

A principal investigator is one who is in charge of a laser laboratory where class 3B or class 4 lasers and laser systems are operated and is ultimately responsible for the safe use of lasers under his/her authority. The principal investigator may delegate some of his/her responsibilities to a laser supervisor. However, the principal investigator cannot discharge these responsibilities to a laser supervisor. The principal investigator has the following responsibilities:

- Register all class 3B or class 4 lasers or laser systems with EHS.
- Identify all class 3B and class 4 laser supervisors and workers under his/her authority to the LSO by completing the Authorized Laser User Form and posting in a prominent place near the laser.
- Provide each laser supervisor/worker training in the safe operation of the specific laser system that he/she will operate.
- Ensure that laser supervisors/workers have completed SFU EHS Laser Safety training prior to working with or in proximity of class 3B or class 4 lasers or laser systems. If this is not possible, provide (either personally or through a laser supervisor) appropriate instruction and supervision until training is available. Only trained and authorized laser supervisors/workers are permitted to operate or work in proximity of class 3B or class 4 lasers or laser systems.
- Ensure that all engineering controls are in place and all administrative procedure controls are followed.
- Provide and enforce the use of appropriate personal protective equipment when required.
- Provide written standard operating procedures (SOPs) and alignment/maintenance procedures for all class 3B and class 4 laser/laser systems and to ensure that each laser is used only under conditions and in locations which meet the requirements of the SOP(s). These SOPs are to be posted in a visible area in the laser working area.
- Not permit the operation of a laser unless there is adequate control of laser hazards to employees, visitors, and the general public.
- Not permit operation of a new or modified class 3B or class 4 laser or laser system under his/her authority without the approval of the LSO. Submit plans for new class 3B or class 4 laser installations or modifications to the LSO for approval.
- Ensure that all class 3B or class 4 lasers or laser systems are securely stored or disabled (for example by removal of the key) when not operating and to prevent unauthorized use.
- Ensure that all laser workers and supervisors participate in SFU's medical surveillance program.
- Ensure that any spectators are properly informed and protected from potential hazards.
- Participate with the LSO during laser safety inspections and correct any unsafe conditions in a timely manner.
- Report any actual or suspected accidents or incidents to EHS. If necessary, assist in obtaining appropriate medical attention for any person involved in a laser accident.
- Instruct workers to report all incidents and accidents to their supervisor and EHS and to seek medical attention within two hours of an exposure (or suspected exposure).

2.2 Laser worker

The laser worker is one who operates or works in proximity to class 3B or class 4 laser/laser systems. The laser worker has the following responsibilities:

- Complete and attend all required training, online courses, education and job/task-specific training.
- To not energize or work with or near a laser unless authorized by the laser supervisor or by the principal investigator.
- To comply with all the safety rules, practices, requirements, written SOPs and other procedures prescribed by the laser supervisor, the principal investigator and the LSO.
- To be familiar with all operational procedures and specific safety hazards of the class 3B or class 4 laser/laser systems that he/she will operate or work with.
- To operate class 3B and class 4 laser/laser systems only under the conditions authorized by the laser supervisor or principal investigator.
- To utilize exposure control measures such as: engineering controls, safe work practices and personal protective equipment when working with or near a laser.
- To report all unsafe conditions to the laser supervisor or principal investigator.
- To participate in the University's medical surveillance program.
- To immediately report any known or suspected accidents to the laser supervisor/principal investigator. If the laser supervisor and the principal investigator are not available, the worker shall notify the LSO.
- Shall not permit spectators within a laser controlled area which contains a class 3B laser and shall not permit spectators within a laser controlled area which contains a class 4 laser unless appropriate approval from the principal investigator or laser supervisor has been obtained; the degree of hazard and avoidance procedures has been explained; and appropriate protective measures are taken.
- Report all incidents and accidents to their supervisor and EHS and to seek medical attention within two hours of an exposure (or suspected exposure).
- Refuse work if there is a reasonable perception the task puts either themselves or others at risk.

2.3 Laser Safety Officer (LSO)

The LSO is responsible for the day-to-day implementation of the laser safety regulations and procedures. The LSO must be trained on potential hazards, control measures, applicable standards, and medical surveillance as it pertains to laser safety.

The LSO must perform all required activities on behalf of SFU as outlined by the applicable regulations. The LSO has the responsibility to:

- Advise the URSC on matters regarding laser hazards and laser safety, including what is required to set up and maintain an adequate laser safety program.
- Be available for consultation on problems dealing with laser sources and potential hazards of such equipment.

- Develop, update, recommend and implement policies and procedures for the safe use of lasers in accordance with WorkSafeBC guidelines and those of other pertinent regulatory agencies and safety codes.
- Maintain an inventory of laser equipment at SFU.
- Classify or verify the classifications of lasers and laser systems used at SFU.
- Review and approve specific operating procedures for each application for use of lasers.
- Evaluate potential hazards of laser work areas, including the establishment of Nominal Hazard Zones (NHZ).
- Ensure that prescribed control measures are in effect, recommend alternatives where necessary, and perform periodic audits of the functionality of these control measures.
- Approve new laser installation facilities and laser equipment, and approve modifications to existing facilities and equipment.
- Approve standard operating procedures, laser alignment procedures, and other procedures that may be necessary for administrative and procedural control measures.
- Approve area warning signs and equipment labels.
- Ensure that education and training is provided in accordance with ANSI standards.
- Determine personnel categories for medical surveillance in accordance with ANSI standards.
- Ensure that the appropriate records are maintained regarding training and medical examinations where applicable.
- Investigate accidents and incidents and initiate appropriate action.
- Maintain LSO certification and designation.
- Review at least annually this SFU Laser Safety Manual and revise it as needed.

3. Definitions

See Appendix A for a list of defined terms used in the American National Standards Institute ANSI Z136.1 (2014) – "Safe Use of Lasers" and in this manual.

4. Training

All laser workers including faculty, staff, students and volunteers are required to:

- complete the SFU Laser Safety Orientation;
- complete on-the-job training in the safe operation of the specific laser system that he/she will operate;
- understand all applicable safety rules, codes and emergency procedures laid out in this SFU Laser Safety Manual;
- understand the contents of the Standard Operating Procedures (SOPs) for the specific laser system that will be operated; and
- be authorized by the responsible user/owner.

5. Class 3B and class 4 laser registry

The laser safety officer (LSO) and the SFU University Radiation Safety Committee (URSC) are required to maintain a laser inventory for all class 3b and class 4 lasers at Simon Fraser University in accordance with SFU's Non-Ionizing Radiation Safety (R 20.05) policy.

Principal Investigators (or their designates) are responsible for registering their class 3B and class 4 lasers with the laser safety officer (LSO) via the online SFU Laboratory hazard inventory system here: https://labhazindex.its.sfu.ca/Home.

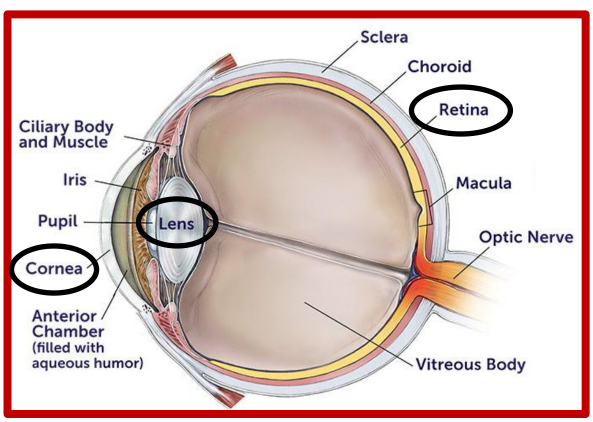
A record of all class 3B and class 4 laser and laser systems is required:

- to identify areas where class 3B and class 4 lasers are present so that appropriate administrative and engineering controls may be put in place; and
- to enable the laser and laser systems to be inspected on a regular basis for compliance with SFU's Laser Safety Program.

6. Laser beam hazards

A laser produces an intense, highly directional beam of light. Exposure to laser radiation can result in eye and skin damage. The extent of the damage depends on the wavelength and intensity of the radiation, and on the duration of the exposure. Research relating to injury thresholds of the eye and skin has been carried out in order to understand the biological hazards of laser radiation. It is now widely accepted that the human eye is almost always more vulnerable to injury than human skin.

The eye (see figure below) is comprised of various structures that when damaged can result in injuries ranging from minor irritation, to total blindness. Damage may occur from direct beam, specular or diffuse reflections from lasers. This is why a major component of any laser safety program involves control measures to prevent exposure to the eye. The potential injury to the skin or eye can be significant and permanent, so every precaution must be taken to avoid this. These precautions are outlined in the Control Measures (Section 8).



The table below presents a summary of the effects of different wavelengths on the eye and skin.

Retinal hazard region

Wavelength range (nm)	Eye Damage	Skin damage
UV-C (200-280)	Photokeratitis	Erythema and cancer
UV-B (280-315)	Photokeratitis	Accelerated skin ageing and increased pigmentation
UV-A (315-400)	Photochemical reaction	Pigment darkening, photosensitive reaction and sunburn
Visible (400-780)	Photochemical cataract and thermal retinal injury	Photosensitive reaction and sunburn
IR-A (780-1400)	Cataract retinal burn	Skin burn
IR-B (1400-3000)	Corneal burn, aqueous flare, possible cataract	Skin burn
IR-C (3000-1mm)	Corneal burn	Skin burn

7. Non beam hazards

Non-beam hazards often exist in laser-related operations and can pose significant health and safety risks. All non-beam hazards must be addressed in SOPs. Examples of non-beam hazards may include:

7. 1 Electrical hazards from power supplies

Both Pulsed and Continuous Wave lasers may have high voltage and high current power supplies and pulsed lasers utilize capacitor (aka condenser) banks. Some gas lasers have radiofrequency power supply circuits. In general, electrical equipment presents the following hazards: shock causing burns, electrocution, resistive heating, arc flash, and ignition of flammable materials. All components of a laser system must meet CSA or equivalent electrical certifications approved by the Electrical Safety Authority. An emergency stop switch can serve to eliminate electrical hazards in an emergency.

7.2 Laser generated air contaminants (LGAC)

Air contaminates may be generated by the interaction of the laser radiation with the target material or other components in the optical path of the laser beam. The types of contaminates that are generated vary from toxic (methyl methacrylate) and carcinogenic (benzene) chemical compounds to hazardous biological agents (microorganisms). LGACs are usually generated when the beam irradiance exceeds 107 W/cm^2 due to the vaporizing effect of the laser radiation on the absorbing material at its surface. If LGAC production is suspected, control measures must be employed to ensure that the concentration of the LGAC is less than the occupational exposure limit specified in the Chemical Hazards Regulation. The control measures commonly employed include process isolation and exhaust ventilation.

7.3 Fire hazards

Irradiance levels in excess of 10 W/cm^2 can ignite combustible material. Most class 4 lasers have irradiance levels exceeding 10 W/cm^2 (or beam powers exceeding 0.5W) and are therefore fire hazards. Flammable substances can be ignited at even lower irradiance levels making class 3B lasers possible fire hazards in the presence of flammable substances.

Barriers and enclosures around a laser must be capable of withstanding the intensity of the beam for a specific period of time without producing smoke or fire. It is important to obtain information from the manufacturer on the properties of the barrier or enclosure to ensure it will provide adequate protection under worse case conditions of exposure. Other items such as unprotected wire insulation and plastic tubing can catch on fire if exposed to sufficiently high reflected or scattered beam irradiance. When working with invisible wavelength lasers this should be kept in mind since it may not be obvious that these surfaces are exposed. The control measures include using non-combustible material in the laser-controlled area especially in the beam path and having adequate fire protection of the facility including sprinkler systems, fire extinguishers, etc.

7.4 Non beam radiation

Radiation is not only produced by the primary laser beam, but may also be produced by system components or the beam's interaction with materials. It can be X-ray, ultraviolet, visible, infrared, microwave or radiofrequency radiation that is generated by the laser power supply, discharge lamp or plasma tube. It can also be emitted from plasma produced by metal targets after the absorption of pulsed laser radiation in excess of 10^{12} Wcm^{-2}.

X radiation may be generated by electronic components of the laser system, e.g., high-voltage vacuum tubes, usually greater than 15 kV, and from laser-metal induced plasmas. Ultraviolet (UV) and visible radiation may be produced by laser pump lamps and during laser-matter interactions. In the case of Electric, Magnetic and Electromagnetic Fields, MPEs for exposure to such fields are found in the IEEE Standards for Safety Levels with Respect to Human Exposure to Electromagnetic (C95.6-2002) or Radio Frequency Fields (C95.1-2019). Finally, plasma generated from high power laser interaction with targets may contain significant amount of UV, which may require control measures.

Contact EHS for assistance with radiation risk assessment and determining appropriate control measures (e.g. shielding, personal protective equipment).

7.5 Explosion hazards

High pressure arc lamps, filament lamps, capacitor banks, target material or items in the path of the laser have the potential for disintegrating, shattering or exploding. Gases used as part of the laser itself or as part of the target material can become heated and explode. Where an explosion hazard exists, adequate enclosures must be installed to protect persons and equipment from the potential effects of the explosion.

7.6 Compressed gases

There are a variety of gases used in laser systems with varying toxic and hazardous properties. All compressed gases are physical hazards by virtue of the high pressure under which the gas is contained. If the gas is released in a rapid and uncontrolled fashion due to a rupture of the cylinder head, the cylinder can become a dangerous projectile causing damage and injury. If the gas is toxic (carbon monoxide) or corrosive (hydrogen chloride) it can burn tissue and cause pulmonary edema if allowed to leak into the work space. Even an inert gas such as argon or helium can cause asphyxiation if it leaks into an enclosed space and displaces oxygen. Safety control measures must be used with compressed gases. Please refer to the Chemical safety fact sheet for compressed gases here to review requirements for gas cylinders.

7.7 Laser dyes and solvents

Some lasers use dyes dissolved in a solvent as the laser medium. The dye is a fluorescent organic compound that may be toxic, mutagenic or carcinogenic. The solvent may be flammable and easily absorbed through the skin carrying the dye compound with it. Therefore, care must be exercised in preparing the dye solutions, transferring the dye solutions into the laser cavity and in cleaning or maintaining the laser system. The safety control measures used with laser dye solutions include:

- Safety Data Sheet available and referenced;
- use of less hazardous solvents when possible;
- use of personal protective equipment (gloves, lab coat);
- use of fume hoods or glove boxes to prepare dye solutions; and
- containment of dye solution transfer pumps and reservoirs.

7.8 Laser and Laser Waste disposal

Laser users have an obligation to ensure the safe and responsible disposition of all laser classes, especially Class 3B and Class 4 lasers and laser components. The LSO must be notified prior to relocation, transfer or disposal.

7.8.1 Laser disposal

Recommended methods of disposal include:

a) Donation to an organization (e.g. academic institution, industrial company, hospital) with a need for such a device. The donor should ensure that the equipment being given complies with all applicable product safety standards, and is provided with adequate safety instructions for operations and maintenance. The donor should ensure that the laser will be used by individuals who are trained in laser safety. Additionally, any organization that receives a Class 3b or Class 4 laser must have an appointed LSO.

b) Return the laser to the manufacturer for credit onto a new laser if applicable

c) Eliminate the possibility of activating the laser by removing all means by which it can be electrically activated. After this the laser can be disposed of by contacting the Laser Safety

Officer. Use of the last method is limited due to land fill restrictions and the possible presence of hazardous materials inside the laser components, such as mercury switches, oils, and other chemicals. It is best to discuss this problem with the Laser Safety Officer.

As of June 2011 it became illegal to sell class 3B and 4 lasers to general consumers per Section 2 of the Canada Consumer Product Safety Act. These classes of lasers can only be sold to academic, research, or commercial institutions. Re-selling of Class 3B and 4 lasers or laser systems to persons not fitting this criteria is strictly prohibited.

7.8.2 Laser Waste disposal

Proper waste disposal of contaminated laser-related material, such as filters, organic dyes, and solvent solutions shall be handled in conformance with appropriate federal, provincial and local guidelines. Please contact the LSO.

8. Control measures

Control measures are devised to reduce the possibility of exposure of the eye or skin to hazardous levels of laser radiation. Substitution of engineering controls with administrative controls may be done with the approval of the Laser Safety Officer (LSO). The control measures below are adapted from ANSI Z136.1. Control measures can be divided into three areas, in order of preference:

- **Engineering controls**, such as barriers, beam blocks, interlocks, etc.
- **Administrative controls**, such as training, signs, labels, procedures, etc.
- **Personal protective equipment (PPE),** such as laser protective eyewear and skin coverings.

8.1 Control measures for class 3B lasers

Control measures for class 3B lasers are listed below (and on the following page).

1. Appropriate warning sign(s) are posted.
2. Operation by qualified and authorized personnel.
3. Operation under the direct supervision of an individual knowledgeable in laser safety.
4. Located so that access to the area by spectators is limited.
5. Any potentially hazardous beam is terminated in a beam stop of an appropriate material.
6. Only diffuse reflective materials are in or near the beam path, where feasible.
7. Personnel within the controlled area are provided with the appropriate eye protection if there is any possibility of viewing the direct or reflected beams.
8. The laser is secured such that the beam path is above or below eye level of a person in any standing or seated position
9. All windows, doorways, open portals, etc. from an indoor facility are either covered or restricted in such a manner as to reduce the transmitted laser radiation to levels at or below the appropriate ocular MPE.

10. Storage or disabling (for example, removal of the key) of the laser or laser system is required when not in use to prevent unauthorized use.

8.2 Control measures for class 4 lasers

In addition to fulfilling all of the control measures for class 3B lasers (Section 8.1) class 4 laser controlled areas must also incorporate the following:

1. All personnel entering a class 4 controlled area must be appropriately trained, provided with appropriate protective equipment, and follow all applicable administrative and procedural controls.
2. All class 4 area/entryway safety controls must allow both rapid entrance and exit to the laser controlled area under any conditions.
3. For emergency conditions, there must be a clearly marked "Panic Button" (switch or equivalent device) to quickly deactivate the laser or reduce the output to safe levels.
4. In addition, the class 4 laser controlled area must incorporate Procedural Area or Entryway Safety Controls. Where door interlocks are not feasible or are inappropriate, the following procedural controls apply:

    a) All authorized personnel must be adequately trained and provided with adequate personal protective equipment upon entry.
    b) A door blocking barrier/screen/curtain, etc., must be used to block or attenuate the laser beam at the entryway to assure that laser radiation outside the area does not exceed the MPE and that no one receives exposure above the MPE immediately upon entry.

    In this case, there shall be a warning light or sound at the entryway indicating that the laser is energized and operating. A lighted warning sign or a flashing light are two examples of methods to appropriately accomplish this requirement.

8.3 Engineering controls

Although commercial laser products will be certified by the manufacturer and will incorporate some engineering controls, the use of the additional controls outlined in this section shall be considered in order to reduce the potential for hazard associated with some applications of lasers and laser systems.

The following table summarizes the engineering control measures that are normally required for class 3B and class 4 laser/laser systems.

Engineering control measures	Laser classification	
	3B	**4**
Protective housing	**Y**	**Y**
Without protective housing	**LSO to determine**	
Interlocks on protective housing	**Y**	**Y**
Service access panel	**Y**	**Y**
Key control	**O**	**Y**
Viewing portals (reduce light below MPE)	**Y**	**Y**
Collecting optics (reduce light below MPE)	**Y**	**Y**
Enclosed beam path	**NC**	**NC**
Limited open beam path	**NHZ**	**NHZ**
Totally open beam path	**NHZ**	**NHZ**
Labels	**Y**	**Y**
Area posting	**Y**	**Y**
Indoor laser controlled area	**Y**	**Y**
Temporary laser controlled area	**Y**	**Y**
LEGEND **Y --- Required** **O --- Optional** **NC --- No further controls required** **NHZ --- Nominal Hazard Zone analysis required by LSO**		

8.3.1 Protective housing

A protective housing is the physical cover or enclosure around the resonator cavity of the laser and it includes the exit port or aperture for the laser light. The protective housing prevents direct access to the internal optical components of the laser and protects persons from the laser light inside the housing. The protective housing may include panels, which permit access to the internal laser radiation. If a user-created enclosure does not meet the requirements of a protective housing (e.g., a non-interlocked cover), it is only considered as a barrier or curtain and other controls are required per section 6.3.2 Laser operation without protective housing. The protective housing limits access to other associated radiant energy emissions and electrical hazards. Normally, this protective housing is provided by the manufacturer.

8.3.2 Laser use without protective housing

In some applications of research and development, the operation of lasers or laser systems without a protective housing may become necessary. In such cases, the LSO shall determine the hazard and ensure that controls are instituted appropriate to the class of maximum accessible emission to ensure safe operation. These controls may include, but are not limited to:

- Access restriction
- Eye protection
- Area controls
- Barriers, shrouds, beam stops, etc.
- Administrative and procedural controls
- Education and training.

8.3.3 Interlocks on protective housing

A protective housing interlock is an internal switch, which is activated when the protective housing or service access panel on the protective housing is opened or removed, and which automatically causes laser operations to terminate. The interlock is designed to protect persons from exposure to laser light should the laser not be turned off before the housing or panel is removed. The interlock can be defeated so that internal alignment of the laser beam can be performed, but this action usually requires a special tool or knowledge of the laser system to avoid casually overriding this protective feature. There must be a label near the interlock to warn persons of the presence of hazardous radiation if the interlock is defeated.

The protective housing interlock shall not be defeated or overridden during operation unless the provisions of "Laser Use without Protective Housing" (above) have been fully implemented.

8.3.4 Service access panels

Service access panels, which are portions of the protective housing and are intended to be removed only by service personnel, permit direct access to laser radiation.

They must either:

1. Be interlocked (fail-safe interlock not required), OR
2. Require a tool for removal and shall have an appropriate warning label.

8.3.5 Key control

All class 4 lasers shall be provided with a master switch, which is operated by a removable key or coded access (such as a computer code).

8.3.6 Viewing portals and display screens

All viewing portals and/or display screens included as an integral part of a laser shall incorporate a suitable means (such as interlocks, filters, attenuators) to maintain the laser radiation at the viewing position at or below the applicable MPE for all conditions of operations and maintenance.

8.3.7 Collecting optics

All collecting optics (such as lenses, telescopes, microscopes, endoscopes, etc.) intended for viewing use with a laser shall incorporate suitable means (such as interlocks, filters, attenuators) to maintain the laser radiation transmitted through the collecting optics to levels at or below the appropriate MPE, under all conditions of operation and maintenance.

8.3.8 Enclosed beam path

In applications of class 3B or class 4 lasers or laser systems where the entire beam path is enclosed, and the enclosure fulfills all the requirements of a protective housing (i.e., limits the laser radiation exposure at or below the applicable MPE), no further controls are required.

8.3.9 Limited open beam path

Where the beam path is confined to significantly limit the degree of accessibility of the open beam, a hazard analysis shall be effected by the LSO to establish the NHZ.

8.3.10 Totally open beam path

In applications of class 3B or class 4 lasers or laser systems where the entire beam path is unenclosed, a laser hazard analysis is required (in conjunction with the LSO) to establish the NHZ. The analysis will define the area where laser radiation is accessible at levels above the appropriate MPE and will define the zone requiring control measures. A **laser controlled area** shall be established in this zone and appropriate control measures shall be implemented within the NHZ based on the classification associated with the maximum level of accessible laser radiation.

8.3.11 Remote interlock connector

The remote interlock connector (e.g. "Panic Button") deactivates the laser or reduces the accessible radiation to levels at or below the applicable MPE.

8.3.12 Beam stop or attenuator

Each class 4 laser or laser system must be provided with a permanently attached beam stop or attenuator capable of preventing the emission of laser light in excess of the MPE when the beam is not required.

8.3.13 Activation warning systems

An activation warning system is required on all class 4 lasers or laser systems. This could be an audible system e.g., an alarm, or a warning light (visible through protective eyewear), or a verbal "countdown" command during activation or start-up of the laser.

8.3.14 Emission delay

This is a warning system, which provides sufficient time prior to emission of laser radiation to allow appropriate action to be taken to avoid exposure to the laser radiation.

8.3.15 Equipment labels

All commercial class 3B and class 4 lasers are labeled. Home built class 3B and class 4 lasers shall have appropriate warning labels affixed to a conspicuous place on the laser housing or control panel.

8.3.16 Area posting

An area, which contains a class 3B or class 4 laser or laser system shall be posted with appropriate signage. Also, a notice sign shall be posted outside a temporary laser controlled area. Only signs approved by the LSO will be posted.

8.3.17 Indoor laser controlled area

When the beam path of a class 3B or class 4 laser or laser system is totally open, a laser controlled area must be established and adequate control measures must be implemented. Please refer to Section 8.1 and 8.2.

8.3.18 Temporary laser controlled area

Where the removal of panels or protective housings, over-riding of protective housing interlocks, or entry into the NHZ becomes necessary (such as for alignment, maintenance or service), and the accessible laser radiation exceeds the applicable MPE, a temporary laser controlled area shall be set up. Such an area by its nature will not have the built-in protective features of a permanent laser controlled area. However, this area shall provide all safety requirements for personnel, both within and outside the area and a sign shall be posted outside the temporary laser controlled area to warn of the potential hazard.

8.4 Administrative and procedural controls

Engineering controls must be given primary consideration in instituting a control measure program for limiting access to laser radiation. If some of these engineering controls are impractical or inadequate, then administrative and procedural controls that provide equivalent protection shall be used.

Administrative and procedural controls are methods or instructions which specify rules, or work practices or both, which implement or supplement engineering controls and which may specify the use of personal protective equipment.

The following table summarizes the administrative and procedural control measures that are normally required for class 3B and class 4 laser/laser systems:

Administrative and procedural control measures	**Laser classification**	
	3B	**4**
Standard operating procedures	**O**	**Y**
Output emission limitations	**LSO to determine**	
Laser worker training	**Y**	**Y**
Authorized personnel	**Y**	**Y**
Alignment procedures	**Y**	**Y**
Eye protection, if MPE is exceeded	**Y**	**Y**
Skin protection, if MPE is exceeded	**Y**	**Y**
Spectator control	**O**	**Y**
Homebuilt/modification of laser systems	**LSO will classify**	
Entryway controls	**X**	**Y**
Laser controlled area warning signs	**Y**	**Y**
Area warning device	**O**	**Y**
Protective barriers and curtains	**O**	**Y**
LEGEND		

Y	**--- Required**
O	**--- Optional**

8.4.1 Standard operating procedures

Standard operating procedures (SOPs) for class 4 laser/laser systems shall be maintained with the laser equipment and must always be available as a reference for all laser users; SOPs may include the laser instruction manual (prepared by the manufacturer) and as appropriate, additional written information to ensure compliance with good work practices and safety.

SOPs are recommended for class 3B laser/laser systems and required for class 4 laser/laser systems. SOPs shall address specific safety considerations during beam alignment, normal experimental operations (such as laser start-up and shut down), servicing and any non-beam hazards that might exist. Safety precautions (such as stray beam/unwanted reflection checks, beam blocks, avoidance of the beam on a horizontal plane with the users eyes, beam enclosures, eyewear, hands-on training, etc.) must be described.

8.4.2 Output emission limitation

If excessive power or radiant energy is accessible during operation or maintenance of a class 3B or class 4 laser or laser system, the laser user must take action as required to reduce the levels of accessible power or radiant energy to that which is commensurate with the required application.

8.4.3 Laser worker training

Education and training shall be provided for all laser users (See section 4). The level of training shall be commensurate with the level of potential hazard.

8.4.4 Authorized personnel

Lasers shall be operated, maintained or serviced by authorized personnel.

8.4.5 Alignment procedures

Laser incident reports have repeatedly shown that an ocular hazard may exist during beam alignment procedures. Alignment shall be performed in such a manner that the primary beam, or a specular or diffuse reflection of a beam, does not expose the eye to a level above the applicable MPE. Written SOPs outlining alignment methods shall be available and followed.

8.4.6 Protective equipment

Eye protection (goggles or spectacles) or skin protection (clothing and gloves) and other devices which have been specifically selected for suitable protection against laser radiation may be required when other control measures are inadequate to eliminate potential exposure in exposure in excess of the applicable MPE.

8.4.7 Spectator control and requirements for restricting access

Spectators shall not be permitted within a laser-controlled area unless:

- appropriate approval from the supervisor has been obtained;

- the degree of hazard and avoidance procedure has been explained; and
- appropriate protective measures are taken.

A spectator is anyone not directly associated with the laser facility (e.g. guests/visitors, service personnel, non-laboratory personnel) visiting or wishing to enter the laser area. Service personnel (Facilities Services, Contractors, Janitors, Campus Public Safety and IT Services) may need to enter class 4 laser controlled areas to complete routine maintenance (e.g., inspection of fire extinguishers or emergency washing facilities) and to provide janitorial services, or during emergency situations (e.g., flooding or medical issues), times of repair and renovations. Please be aware that entry may create a hazard to the individual.

To mitigate this hazard please ensure a “Restricted Access Area” sign is used at the entrances to class 4 laser controlled areas to: a) prevent inadvertent entry and; b) alert service personnel that in order to enter, they must be escorted by individuals responsible for the laser area.

9. Personal protective equipment (PPE)

9.1 General

Enclosure of the laser equipment or beam path is the preferred method of control, since enclosure will isolate or minimize the hazard. If enclosure is not entirely feasible and other control measures do not adequately prevent access to direct or reflected beams at levels above the Maximum Permissible Exposure (MPE), it may be necessary to use personal protective equipment (PPE) to provide protection against laser radiation.

9.2 Laser eye protection

*****Note: Even if you are wearing protective eyewear, never look directly into any laser beam**

Lasers can produce serious injury to the eyes if adequate protection is not worn. A laser eye protection device is a filter which is designed to reduce light transmission of a specific wavelength, or range of wavelengths, to a safe level while maintaining adequate light transmission at all other wavelengths. Eye-protection devices which are specifically designed for protection against the emitted wavelength of the laser should be used when engineering and procedural controls are inadequate.

The Principal Investigator must ensure that laser protective eyewear is available and worn by all personnel within the Nominal Hazard Zone of class 3B and class 4 laser/laser systems where the exposures above the MPE can occur.

The Principal Investigator shall provide laser protective eyewear that is clearly labeled with the optical density and the wavelength for which protection is afforded.

Laser supervisors/users/laser laboratory workers shall wear protection as required and shall inspect laser protective eyewear for damage prior to use, replacing eyewear, if faulty. Also, protective eyewear shall be cleaned periodically, according to the manufacturer's instructions.

The attenuation factor (optical density) of the laser protective eyewear at each laser wavelength shall be specified by the Laser Safety Officer (LSO).

9.3 Skin protection

For class 3B and 4 lasers operating in the ultraviolet range (180 to 400 nm), skin protection shall be used if exposures are anticipated at or near the applicable MPE. Types of skin protection would include laboratory coats, tightly woven fabrics, opaque gloves and full-face shields.

10. Medical surveillance program

All class 3B and class 4 laser supervisors/users/laser laboratory workers are required to participate in SFU's laser medical surveillance program. An acknowledgement form must be signed (See Appendix B).

The ANSI Standard (ANSI Z136.1) has made baseline, annual and termination eye exams optional. **Eye exams are required for incidents or suspected exposures.**

All SFU personnel who work with class 3B or class 4 lasers/laser systems are required to acknowledge the SFU Laser Safety – Medical Surveillance Program by completing the Medical Surveillance Form (Appendix A) to **either**:

- Request the Laser Safety Eye Exam (medical records and test results pertaining to this program will be retained by SFU), or
- Refuse the Laser Safety Eye Exam (laser user retains ability to opt into the Program if he/she changes their mind at a later date).

SFU personnel who work with class 3B or class 4 lasers/laser systems are offered cost coverage of the following eye examinations:

- Periodic (annual) eye exam - Available but not required.
  - Please contact the Laser Safety Officer for details.
- **Following a suspected or actual laser-induced injury – REQUIRED**.
  - Shall be performed as soon as possible (within 48 hours) when a suspected injury or adverse effect from a laser exposure occurs. Must be conducted by an ophthalmologist as specified in ANSI Z136.1 as soon as possible following the incident/exposure. For Incident related eye exams, it is important that immediate care be administered promptly and as such, the most immediate care should be sought. The relevant eye examinations are described in Appendix C.

Procedure for obtaining an eye examination

Where the eye examination is not covered by medical insurance, Simon Fraser University will cover the cost of the examination. Upon approval of the Medical Surveillance form, the relevant American

National Standard (ANSI Z136.1-2014 *Safe use of lasers* - Section 6 and Appendix F - Medical Examinations) guidelines on eye exam will be sent to the Applicant. These are available in Appendix C.

Before your eye exam

1. Ensure that you have a qualified and licensed ophthalmologist or optometrist.
2. Arrange transportation – Be advised that your pupils and your vision may be too blurry to drive for approximately four hours following dilation.
3. Provide your ophthalmologist/optometrist with the appropriate ANSI Z136.1 guidelines on eye exam.

At your eye exam and after

1. You will have to pay for the examination up front.
2. Keep the original receipt of your payment and request reimbursement through SFU EHS.
3. Your medical report is sent directly to the SFU EHS Laser Safety Officer from your eye examiner.

Please contact the SFU Laser Safety Officer (email: mszczepi@sfu.ca; Tel: 778.782.7265) with any questions or concerns.

11. Reporting

All incidents, accidents, exposure (including suspected exposures) and near-miss incidents must be reported at SFU via the online webform.

These must be immediately reported to your supervisor and to EHS so a follow-up investigation can be conducted.

Safety Facts!

- The most common causes of laser accidents in research labs are the following:
- Not wearing appropriate safety goggles
- Not reducing power for alignment procedures, or unintended power increase
- Stray beams left uncontained by beam stops or other barriers

12. Inspections

Periodic inspections by the LSO and/or their designate(s) are required for all laboratories at SFU working with class 3B and class 4 lasers and laser systems. These inspections serve to ensure SFU laboratories are in accordance with regulations and in compliance with all applicable laser standards and guidelines.

13. Annual review

The SFU Laser Safety Officer is responsible for reviewing, at least annually, the Laser Safety Manual and revising it as needed.

Appendix A – Definitions

The following terms are used in the American National Standards Institute ANSI Z136.1 (2014) – "Safe Use of Lasers" and in this manual.

administrative control measure. Control measures incorporating administrative means [e.g., training, safety approvals, LSO designation, and standard operating procedures (SOP)] to mitigate the potential hazards associated with laser use.

authorized personnel. Individuals approved by management to operate, maintain, service, or install laser equipment.

average power. The total energy in an exposure or emission divided by the duration of that exposure or emission.

aversion response. Closure of the eyelid, eye movement, pupillary constriction, or movement of the head to avoid an exposure to a noxious or bright light stimulant. In this manual, the aversion response to an exposure from a bright, visible, laser source is assumed to limit the exposure of a specific retinal area to 0.25 seconds or less.

beam. A collection of light/photonic rays characterized by direction, diameter (or dimensions), and divergence (or convergence).

beam diameter. The distance between diametrically opposed points in that cross-section of a beam where the power or energy is 1/e (0.368) times that of the peak power or energy.

beam divergence. For purposes of this manual, divergence is the increase in the diameter of the laser beam with distance from the beam waist, based on the full angle at the point where the irradiance (or radiant exposure for pulsed lasers) is 1/e times the maximum value.

collecting optics. Lenses or optical instruments having magnification and thereby producing an increase in energy or power density. Such devices may include telescopes, binoculars, microscopes, or loupes.

continuous wave (CW). In this manual, a laser operating with or modeled as having a continuous output for a period > 0.25 s is regarded as a CW laser.

control measure. A means to mitigate potential hazards associated with the use of lasers. Control measures can be divided into three groups: engineering, procedural (administrative), and personal protective equipment (PPE).

controlled area. An area where the occupancy and activity of those within is subject to control and supervision. *See also:* laser controlled area.

cornea. The transparent outer layer of the human eye that covers the iris and the crystalline lens. The cornea is the main refracting element of the eye.

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.

electromagnetic radiation. The flow of energy consisting of orthogonally vibrating electric and magnetic fields lying transverse to the direction of propagation. Gamma rays, X-rays, ultraviolet, visible, infrared, and radio waves occupy various portions of the electromagnetic spectrum and differ only in frequency, wavelength, and photon energy.

embedded laser. An enclosed laser that has a higher classification than the laser system in which it is incorporated, where the system's lower classification is appropriate due to the engineering features limiting accessible emission.

enclosed laser. A laser that is contained within a protective housing of itself or of the laser or laser system in which it is incorporated. Opening or removal of the protective housing provides additional access to laser radiation above the applicable MPE than possible with the protective housing in place.

engineering control measure. Control measures designed or incorporated into the laser or laser system (e.g., interlocks, shutters, watch-dog timer) or its application.

fail-safe interlock. An interlock where the failure of a single mechanical or electrical component of the interlock will cause the system to go into, or remain in, a safe mode.

infrared (IR). For purposes of this manual, the region of the electromagnetic spectrum between the long-wavelength extreme of the visible spectrum (700 nm) and the shortest microwaves (1000 µm).

intrabeam viewing. The viewing condition whereby the eye is exposed to all or part of a laser beam.

laser. A device that produces radiant energy predominantly by stimulated emission. Laser radiation may be highly coherent temporally, or spatially, or both. An acronym for Light Amplification by Stimulated Emission of Radiation.

laser barrier. A device used to block or attenuate incident direct or diffuse laser radiation. Laser barriers are frequently used during times of service to the laser system when it is desirable to establish a boundary for a controlled laser area.

laser classification. An indication of the beam hazard level of a laser or laser system during normal operation, or the determination thereof. The hazard level of a laser or laser system is represented by a number or a numbered capital letter. The laser classifications are Class 1, Class 1M, Class 2, Class 2M, Class 3R, class 3B and class 4.

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

laser personnel. Persons who routinely work around hazardous laser beams.

laser pointer. A laser or laser system designed or used to specify a discrete point or location, such as those lasers used in classroom lectures or for the aiming of firearms. These products are usually Class 1, Class 2, or Class 3R.

laser product. Any manufactured product or assemblage of components that constitutes, incorporates, or is intended to incorporate a laser or laser system. A laser or laser system intended for use as a component of an electronic product is itself considered a laser product.

laser safety officer (LSO). One who has authority and responsibility to monitor and enforce the control of laser hazards and effect the knowledgeable evaluation and control of laser hazards.

laser system. An assembly of electrical, mechanical, and optical components that includes a laser.

magnified viewing. Viewing an object through an optical system that increases the apparent object size. This type of optical system can make a diverging laser beam more hazardous, (e.g., using a magnifying optic to view the end of an energized optical fiber).

maximum permissible exposure (MPE). The level of laser radiation to which an unprotected person may be exposed without adverse biological changes in the eye or skin.

nominal hazard zone (NHZ). The space within which the level of the direct, reflected, or scattered radiation may exceed the applicable MPE. Exposure levels beyond the boundary of the NHZ are below the applicable MPE.

nominal ocular hazard distance (NOHD). The distance along the axis of the unobstructed beam from a laser, fiber end, or connector to the human eye beyond which the irradiance or radiant exposure does not exceed the applicable MPE.

non-beam hazards (NBH). All hazards arising from the presence of a laser system, excluding direct human exposure to direct or scattered laser radiation.

optically aided viewing. Viewing with a telescopic (binocular) or magnifying optic. Under certain circumstances, viewing with an optical aid can increase the hazard from a laser beam.

optical density (OD). The logarithm to the base ten of the reciprocal of the transmittance at a particular wavelength.

personal protective equipment (PPE). Personal safety protective devices used to mitigate hazards associated with laser use [e.g., laser eye protection (LEP), protective clothing, and gloves].

principal investigator. An individual who has charge if a laser laboratory and/or principal authority for class 3B and/or class 4 laser/laser systems.

protective housing. An enclosure that surrounds the laser or laser system and prevents access to laser radiation above the applicable MPE. The aperture through which the useful beam is emitted is not part of the protective housing. The protective housing limits access to other associated radiant energy emissions and to electrical hazards associated with components and terminals, and may enclose associated optics and a workstation.

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.

pulse-repetition frequency (PRF). The number of pulses occurring per second, expressed in hertz.

pulsed laser. A laser that delivers its energy in the form of a single pulse or a train of pulses. For purposes of this manual, the duration of a pulse is less than 0.25 s.

pupil. The variable aperture in the iris through which light travels to the interior of the eye.

Q-switch. A device for producing very short (~10 – 250 ns) intense laser pulses by enhancing the storage and dumping of electronic energy in and out of the lasing medium, respectively.

Q-switched laser. A laser that emits short (~10 – 250 ns), high-power pulses by means of a Q-switch.

repetitive pulse laser. A laser with multiple pulses of radiant energy occurring in a sequence.

retina. The sensory tissue that receives the incident image formed by the cornea and lens of the human eye.

retinal hazard region. Optical radiation with wavelengths between 400 nm and 1400 nm, where the principal hazard is usually to the retina.

shall. The word *shall* is to be understood as mandatory.

should. The word *should* is to be understood as advisory.

spectator. Anyone not directly associated with the laser facility (e.g. guests/visitors, service personnel, non-laboratory personnel) visiting or wishing to enter the laser area.

specular reflection. A mirror-like reflection.

standard operating procedure (SOP). Formal written description of the safety and administrative procedures to be followed in performing a specific task.

thermal effect. For purposes of this manual, an effect brought about by the temperature elevation of a substance due to absorption of laser energy.

ultraviolet radiation (UV). Electromagnetic radiation with wavelengths between 180 nm and 400 nm.

uncontrolled area. An area where the occupancy and activity of those within is not subject to control and supervision for the purpose of protection from radiation hazards.

viewing window. A visually transparent part of an enclosure that contains a laser process. It may be possible to observe the laser processes through the viewing windows.

visible radiation (light). The term is used to describe electromagnetic radiation that can be detected by the human eye. For purposes of this manual, this term is used to describe wavelengths that lie in the range 400 nm to 700 nm. Derivative standards may legitimately use 380 nm to 780 nm for the visible radiation range.

wavelength. The distance in the line of advance of a sinusoidal wave from any one point to the next point of corresponding phase (e.g., the distance from one peak to the next).

Appendix B – SFU Laser safety medical surveillance acknowledgement form

Applicant (user) information

Surname		**Given name(s)**	
Department		**Phone number**	
Email address		**Status at SFU: graduate student, pdf, staff, etc.**	

Supervisor information

Supervisor's surname		**Supervisor's given name(s)**	
Email address		**Phone number**	

I, ____ (please print your name)

☐ Refuse the offer of an eye examination at this time and retain the option of accepting the offer at a later date.

Or

I, ____ (please print your name)

☐ Require an eye examination for the use of class 3B and class 4 lasers at Simon Fraser University and I authorize Simon Fraser University to receive a copy of my eye examination results.

Applicant Signature: __________________________________ Date:________________________________

Supervisor Signature: __________________________________Date:________________________________

SRS EHS Signature/Approval: __________________________Date:________________________________

The information on this form is collected under the authority of the Freedom of Information and Protection of Privacy Act (R.S.B.C. 1996, c.165). It is related directly to and needed by the University so that SFU can be in compliance with the regulations mandated according to SFU's Radiation Safety Policy (R 20.05) and the American National Standard for Safe Use of Lasers ANSI Z136.1. The information will be used for record keeping and for administering the SFU Laser Safety Program. If you have any questions about the collection, use and disclosure of this information please contact Monica Szczepina, Laser Safety Officer, 8888 University Drive, Burnaby B.C. V5A 1S6, 778.782. 7265.

Appendix C – Excerpts from ANSI National Standard Z136.1-2014 Medical Examinations

6. **Medical Examinations**

6.1 **Examinations Following a Suspected or Actual Laser-Induced Injury.**

Medical examinations shall be performed as soon as practical (usually within 48 hours) when a suspected injury or adverse effect from a laser exposure occurs. In addition to the acute symptoms, consideration shall be given to the exposure wavelength, emission characteristics and exposure situation to ensure appropriate medical referral. See Appendix F for recommended examination protocol commensurate with the observed symptoms and laser system. For injury to the eye from lasers operating in the retinal hazard region, examinations shall be performed by an ophthalmologist.

6.2 **Rationale for Other Medical Examinations.**

The rationale for providing a medical surveillance program for personnel working in a laser environment and specific information of value to examining or attending physicians are included in Appendix F. Medical surveillance should be considered for those who are clearly known to be at risk from particular kinds of laser radiation. Medical surveillance is not recommended for personnel using Class 1, Class 1M, Class 2, Class 2M or Class 3R lasers and laser systems as defined in 3.3, but should be considered for personnel exposed to Class 3B and Class 4 lasers and laser systems. Further information is provided in Appendix F3.1.

Appendix F Medical Examinations

F1. Medical Referral Following Suspected or Known Laser Injury

Any employee with an actual or suspected laser-induced injury should be evaluated by a medical professional as soon as possible after the exposure (usually within 48 hours). Referral for medical examinations shall be consistent with the medical symptoms and the anticipated biological effect (see Appendix H) based upon the laser system in use at the time of the incident. For laser-induced injury to the retina, the medical evaluation shall be performed by an ophthalmologist. Employees with skin injuries should be seen by a physician.

F1.1. **Examination Protocols.** Recommended medical examinations for actual or suspected exposure include but are not limited to those listed below.

F1.1.2 **Ocular History.** The past eye history and family history are reviewed. Any current complaints concerned with the eyes are noted. Inquiry should be made into the general health status with a special emphasis upon systemic diseases that might produce ocular problems with regard to the performance cited in 6.1. The current refraction prescription and the date of the most recent examination should be recorded.

Certain medical conditions may cause the laser worker to be at an increased risk for chronic exposure. Use of photosensitizing medications, such as phenothiazines and psoralens, lower the threshold for biological effects in the skin, cornea, lens and retina of experimental animals exposed to ultraviolet and near ultraviolet radiation. Aphakic individuals would be subject to additional retinal exposure from blue light, near ultraviolet and ultraviolet radiation. Unless chronic viewing of these wavelengths is required, there should be no reason to deny employment to these individuals.

F1.1.3 **Visual Acuity.** Visual acuity for far and near vision should be measured with some standardized and reproducible method. Refraction corrections should be made if required for both distant and near test targets. If refractive corrections are not sufficient to change acuity to 20/20 (6/6) for distance and near vision, a more extensive examination is indicated as defined in F1.1.6.

F1.1.4 **Macular Function.** An Amsler grid or similar pattern is used to test macular function for distortions and scotomas. The test should be administered in a fashion to minimize malingering and false negatives. If any distortions or missing portions of the grid pattern are present, the test is not normal.

F1.1.5 **Color Vision.** Color vision discrimination can be documented by Ishihara or similar color vision tests.

F1.1.6 **Examination of the Ocular Fundus with an Ophthalmoscope or Appropriate Fundus Lens at a Slit Lamp**. This portion of the examination is to be administered to individuals whose ocular function in any of subsections F.1.1.2 through F.1.1.5 is not normal. The points to be covered are:

a) the presence or absence of opacities in the media;

b) the sharpness of outline of the optic disc;

c) the color of the optic disc;

d) the depth of the physiological cup, if present;

e) 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 fovea reflex; and

f) any retinal pathology that can be seen with an ophthalmoscope (hyper-pigmentation, depigmentation, retinal degeneration, exudate, 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.

F1.2 **Skin Examination.** While not required for pre-placement of laser workers, skin examinations are recommended for employees with a history of photosensitivity or working with lasers emitting accessible ultraviolet radiation. Any previous dermatological abnormalities and family history are reviewed. Any current complaints concerned with the skin are noted as well as the history of medication usage, particularly concentrating on those drugs that are potentially photosensitizing.

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

F1.3 **Other Examinations.** Further examinations should be done as deemed necessary by the examiner.

F2. Medical Examinations

F2.1 **Rationale for Examinations**. Past experience has shown that pre-incident examinations would normally not be as extensive as a post incident examination. Therefore, the medical-legal value of pre-examination has been shown to be of limited value with litigation tending to be driven by biophysical measurements of the accident site and the exposure geometry. Individual institutions may provide pre-exposure screening and even continuing surveillance; however, that surveillance is not deemed to be a requirement for safe laser usage.

F2.1.1 **Preassignment Medical Examinations.** One purpose for the use of a preassignment medical examination is to establish a baseline against which damage (primarily ocular) can be measured in the event of an accidental injury. A second purpose is to identify certain workers who might be at special risk from chronic exposure to selected continuous wave lasers. For incidental workers (e.g., custodial, military personnel on maneuvers, clerical and supervisory personnel not working directly with lasers) only visual acuity measurement is required. For laser workers' medical histories, visual acuity measurement, and selected examination protocols are required. The wavelength of laser radiation is the determinant of which specific protocols are required (see F1.1). Examinations should be performed by, or under the supervision of, an ophthalmologist, optometrist or other qualified physician. Certain examination protocols may be performed by other qualified practitioners or technicians under the supervision of a physician. Although skin damage from chronic exposure to laser radiation has not been reported, and indeed seems unlikely, this area has not been adequately studied. Limited skin examinations are suggested to serve as a baseline until future epidemiologic studies indicate whether they are needed or not.

F2.1.2 **Periodic Medical Examinations.** Periodic examinations are not required by this standard. At present, no chronic health problems have been linked to working with lasers. Also, most uses of lasers do not result in chronic exposure of employees even to low levels of radiation. A large number of these examinations have been performed in the past, and no indication of any detectable biological change was noted. Employers may wish to offer their employees periodic eye examinations or other medical examinations as a health benefit. However, there does not appear to be any valid reason to require such examinations as part of a medical surveillance program.

F2.1.3 **Termination Medical Examinations.** The primary purpose of termination examinations is for the legal protection of the employer against unwarranted claims for damage that might occur after an employee leaves a particular job. The decision on whether to offer or require such examinations is left to individual employers.

F3. Medical Surveillance Examinations

F3.1 **Rationale for Surveillance Examinations.** The basic reasons for performing medical surveillance of personnel working in a laser environment are the same as for other potential health hazards. Medical surveillance examinations may include assessment of physical fitness to safely perform assigned duties, biological monitoring of exposure to a specific agent and early detection of biological damage or effect.

Physical fitness assessments are used to determine whether an employee would be at increased or unusual risk in a particular environment. For workers using laser devices, the need for this type of assessment is most likely to be determined by factors other than laser radiation per se. Specific information on medical surveillance requirements that might exist because of other potential exposures (e.g., toxic gases, noise, ionizing radiation) are outside the scope of this appendix.

Direct biological monitoring of laser radiation is impossible, and practical indirect monitoring through the use of personal dosimeters is not available.

Early detection of biological change or damage presupposes that chronic or subacute effects may result from exposure to a particular agent at levels below that required to produce acute injury. Active intervention must then be implemented to arrest further biological damage or to allow recovery from biological effects. Although chronic injury from laser radiation in the ultraviolet, near ultraviolet, blue portion of the visible, and near infrared regions appears to be theoretically possible, risks to workers using laser devices are primarily from accidental acute injuries. Based on risks involved with current uses of laser devices, medical surveillance requirements that should be incorporated into a formal standard appear to be minimal.

Other arguments in favor of performing extensive medical surveillance have been based on the fear that repeated accidents might occur and the workers would not report minimal acute injuries. The limited number of laser injuries that have been reported in the past 30 years and the excellent safety records with laser devices do not provide support to this argument.

F4. Records and Record Retention

Complete and accurate records of all medical examinations (including specific test results) should be maintained for all personnel included in the medical surveillance program. Records should be retained for at least 30 years.

F5. Access to Records

The results of medical surveillance examinations should be discussed with the employee.

All non-personally identifiable records of the medical surveillance examinations acquired in F4 of these guidelines should be made available on written request to authorized physicians and medical consultants for epidemiological purposes. The record of individuals will, as is usual, be furnished upon request to their private physician. All records must be managed in accordance with the Health Insurance Portability and Accountability Act (HIPAA).

F6. Epidemiologic Studies

Past use of lasers has generally been stringently controlled. Actual exposure of laser workers has been minimal or even nonexistent. It is not surprising that acute accidental injury has been rare and that the few reports of repeated eye examinations have not noted any chronic eye changes. For these reasons, the examination requirements of this standard are minimal. However, animal experiments with both laser and narrow-band radiation indicate the potential for chronic damage from both subacute and chronic exposure to radiation at certain wavelengths. Lens opacities have been produced by radiation in the 295 nm to 450 nm range and are also theoretically possible from 750 nm to 1400 nm.

Photochemical retinitis appears to be inducible by exposure to 350 nm to 500 nm radiation. If laser systems are developed that require chronic exposure of laser workers to even low levels of radiation at these wavelengths, it is recommended that such workers be included in the long-term epidemiologic studies and have periodic examinations of the appropriate eye structures.

Epidemiologic studies of workers with chronic skin exposure to laser radiation (particularly ultraviolet) are suggested.