North Dakota State University
Laser Safety

I. Introduction

The laser represents a class of light emitting devices with unique characteristics. Some of these characteristics can result in significant hazards. The light from a laser is collimated, coherent, can be of high intensity, and can cause burns to the eyes or skin or ignite flammable material. Laser power supplies frequently have high voltages at potentially lethal current levels. Some lasers employ potentially hazardous cryogenic fluid for cooling purposes. Manufacturing standards have been established which provide some safety features for lasers which include warning labels, beam shutters, power supply interlocks, and enclosures. In the research laboratory, it is sometimes necessary to disable some of these safety features to perform maintenance or repairs or make modifications to the laser. In addition it is often necessary to work with unenclosed beams of moderate or high power to obtain or adjust an experimental setup. This situation can present potentially hazardous conditions which must be minimized by proper experimental design, engineering controls, personal protective equipment (such as eyewear) and proper training.

II. Purpose

The purpose of these guidelines is to promote safety awareness and encourage safe work practices with lasers.

III. Goals

The goal is to limit the exposure to occupational injury and death. Also, it is the goal to minimize the potentially hazardous conditions related to lasers by using proper experimental design, engineering controls, personal protective equipment (such as eyewear), and completing proper training.

IV. Controlling Laser Hazards

The responsibility for laser safety is primarily that of the investigating scientist under whose direction the laser is being used. The guidelines that follow are intended as an aid in determining the minimum requirements for the safe laboratory use of lasers. The flexibility required in a laboratory limits the ability to establish fixed rules governing laser use and, thus, the guidelines indicate an approach recommended to minimize hazards.

A. A basic approach to laser safety is summarized as follows:
   - Thoroughly evaluate the hazards associated with the specific laser and its use
   - Adequately train personnel in the safe use of lasers
   - Define and provide appropriate protective equipment
   - Reduce laser beam intensities to the minimum required to perform a desired procedure

B. Primary and Significant Hazards: The following are some examples of significant hazard potential issues as well as some suggestions for their mitigation.

Eyes - The primary hazard of lasers is eye damage due to intrabeam viewing. The well-collimated coherent laser beam can be focused to a very small spot on the retina and cause destruction of the retina. For lasers with power less than 1 mW (Class 2) the natural brightness aversion reflex will normally protect the eye from serious injury. For higher power lasers, however, the injury can be instantaneous and permanent. For lasers with power near 0.5 W (and higher) merely the diffuse scattering of the beam can cause serious damage to the eye. It is essential, therefore, to evaluate all possible hazards associated with moderate and high power lasers to limit beam exposure. Be aware of stray back reflections when laser light impinges upon optical components. Use appropriate beam blocks whenever possible.

Skin - Burns can result from acute exposures to high levels of optical radiation. Some specific ultraviolet wavelengths can cause carcinogenesis of the skin.

Even though skin effects have been considered of secondary importance from a safety standpoint, cases of skin damage have been increasing due to the increased use of lasers emitting ultraviolet light and high-power lasers.

Chemical Hazards - Reactions induced by lasers can release hazardous particulate and gaseous products. Some lasers, such as dye lasers, employ chemicals that may be toxic. Laser equipment employing ignitable liquids should have a means to control or contain ignitable liquid spills using noncombustible materials. When ignitable solvents are used, such as in dye lasers, products with the highest possible flash point consistent with the necessary solvent properties should be used. General ventilation safety procedures should be used when lasers are used in this manner.

Electrical Hazards - Laser power supplies often involve potentially lethal voltage and current combinations. Even when the power supply is disconnected, capacitor banks may have dangerous stored electrical energy. Therefore, only qualified personnel shall perform service or maintenance on lasers and their power supplies. At times, access to the laser cavity is required for maintenance of optical components or other purposes while the system is operating. Personnel must be acutely aware of the voltages present within the laser cavity and which components may be energized in order that precautions be taken to avoid contact.

C. Secondary Hazards

Vaporized Target Materials - When the laser beam is capable of vaporizing target material, it may emit toxic contaminants into the laboratory atmosphere. If this is possible, provide suitable local exhaust of laser target areas.

Laser Gases - Some lasers employ flowing gas systems. These gases may be toxic (e.g., CO, HF, etc.) Properly exhaust such gases and otherwise treat them as appropriate to their toxicity or hazard.

Cryogenic Coolants - Some lasers employ cryogenic coolants, and these materials must be properly handled. Address the hazards to skin or eyes associated with direct contact with ultra-cold fluid. Also, provide proper exhaust of evaporating cryogenic liquid if sufficient cryogen is present to create a toxic or oxygen deficiency hazard.

Pump Lamps - Some pump lamps, such as high pressure arc lamps, may be hazardous due to the possibility of lamp explosion. Use appropriate lamp housings when lamps are operating. When handling the lamps, wear appropriate protective clothing and face/eye protection. In addition, some lamps emit substantial amounts of UV or other harmful wavelengths of radiation. Employ proper shields, filters, or personal protective equipment to limit exposure.

Ionizing Radiation - Potentially hazardous x-radiation may be generated from high voltage (>15 kV) power supply tubes.

The basic approach of all laser safety standards has been to classify lasers by their potential hazard based upon there optical emission. Basically, the ANSI classification scheme is used to describe the capability of the laser or laser system to produce injury to personnel. The higher the classification, the greater the potential hazard.

V. Laser Class Properties

Federal law requires the manufacturers of lasers to provide the classification for all lasers produced. If the laser is changed by the user, the classification must be determined and made known to all users.

Class	Properties
1.	Exempt laser or laser systems that cannot, under normal operational conditions, produce a hazard.
2.	Low power visible lasers or laser systems which, because of normal human aversion responses, do not normally present a hazard. They may present some potential for hazard if viewed directly for extended periods of time. Class 2A: Special-purpose lasers not intended for viewing. Their power output is less than 1 mW. Many barcode readers and most laser pointers fall into this category.
3A	Lasers or laser systems that normally would not produce a hazard if viewed for only momentary periods with the unaided eye. They may present a hazard of viewed using collecting optics. Some laser pointers fall into this category.

3B Lasers or laser systems that can produce a hazard if viewed directly. This includes intrabeam viewing or specular reflections. A class 3b laser can produce a hazardous diffuse reflection.

4 Lasers or laser systems that can produce a hazard not only from direct or specular reflection, but also from diffuse reflection. In addition, such lasers may produce fire hazards and skin hazards.

VI. Laser Safety Rules and Procedures

A. Class 1 Lasers

- A warning sign indicating the laser classification should be placed in a visible location on the laser. Unnecessary exposure to Class 1 laser light should be avoided.

B. Class 2 Lasers

- Precautions are required to prevent continuous staring into the direct beam or a beam reflected from a mirror-like surface. In most cases with Class 2 lasers, the natural brightness aversion reflex (blinking) generally provides protection from visible laser light. It is possible, however, to overcome the blink reflex and to stare into a Class 2 laser long enough to damage the eye.

- Class 2A Lasers: This class of lasers causes injury only when viewed for more than 1,000 seconds.

C. Class 3 Lasers

- Class 3A Lasers: In addition to the requirements of Class 2 lasers, precautions are required to prevent intrabeam viewing or specular beam reflections which may enter the eye. Class 3A lasers pose severe hazards when viewed through optical instruments (e.g., microscopes and binoculars).
- Class 3B Lasers: Class 3B lasers will cause injury upon direct viewing of the beam or specular reflections. In addition to the requirements of Class 3A lasers, use the following engineering controls:
  - A protective housing
  - Protective housing interlock systems that prevent emission of laser radiation when the housing is opened
  - Viewing portals in the protective housing with filters and attenuators to preclude the emission of laser light at harmful levels
  - For all optical instruments intended for viewing a laser or laser system, suitable means (e.g., filters, attenuators, or interlocks) to preclude the transmission of laser light in harmful levels under all conditions of operation and maintenance
  - Operate lasers only in controlled areas in order to confine the laser hazards to well-defined spaces that are entirely under the control of

the laser user. The area must be posted with appropriate warning signs that indicate the nature of the hazard and appropriate control measures.

- When the use of uncontained beams is unavoidable, observe the following precautions:
  - Wear protective eyewear
  - Place an appropriate laser hazard warning at all entrances to the area when the laser beam is operating and limit access to the area to authorized personnel
  - Terminate the laser beam at the limit of its useful distance. A dull black (highly absorbing/low reflectance) surface is recommended for visible frequency lasers. Beam traps or terminators with total absorbers appropriate to the wavelength of UV and IR lasers are recommended for those wavelength ranges
  - Minimize specular reflecting surfaces in or near the beam path
  - Light the space containing the laser well to constrict pupils
  - Position the laser and contain the beam, such that the beam does not exit the area of use
  - When it is necessary to align the beam, reduce its intensity as much as practical to reduce hazard potential

D. Class 4 Lasers

- Follow the requirements for Class 3B plus institute the following additional safeguards:
  - Equip all Class 4 lasers with an appropriate locking system to permit only authorized personnel to operate the laser
  - Install electrical connections that allow the laser to be controlled by an area interlock system and remote shut-off devices
  - Provide an integral or permanently attached beam stop or attenuator capable of preventing the emission of laser light at hazardous levels
  - Conduct a hazard review before using a Class 4 laser. Write operating procedures based upon this review
  - Limit access during operation of the laser to authorized personnel
  - Employ a warning device at the area entrance to indicate the presence of the laser beam
  - Enclose the beam path except when beam access is required
  - Use appropriate protective eyewear unless the beam intensity has been reduced to a non-hazardous level
  - Take procedural steps necessary to ensure that hands, arms, or other parts of the body do not intersect the beam
  - Provide for a means to quickly disengage the laser power source from the electrical main during an emergency
  - Use a highly absorbent beam trap of fire retardant materials to terminate the beam

- For infrared lasers (since the beam is invisible), protect areas which are exposed to reflections of the beam by fully enclosing the beam and target area
- For ultraviolet laser beam radiation, provide a beam shield which attenuates the radiation to acceptable levels
- Use a countdown procedure to signify the firing of single pulse lasers to ensure all present are aware of the firing of the laser
- Wear appropriate laser protective eyewear. Clearly label the eyewear with optical density values and wavelengths for which protection is afforded. Wear the eyewear whenever operational conditions may result in potential eye hazard
- Confine indoor laser operations to a light-tight room with interlocked entrances to assure that the laser cannot emit when a door is open

VII. Lasers in Laser Pointing Devices

The potential hazards of laser pointers are limited to the eye. Although with most visible lasers, the largest concern is potential damage to the retina, most laser pointers are not likely to cause retinal damage. The possible exception might be the green light lasers. These lasers emit green beams from frequency doubled Nd: YAG lasers operating at 532 nm and have emissions significantly exceeding the maximum permissible exposure (as per the ANSI laser standard, Z136). The most likely effects from exposure to viewing the beam from a laser pointer are afterimage, flash-blindness and glare.

- Flash-blindness is temporary vision impairment after viewing a bright light. This is similar to looking directly at a flashbulb when having a picture taken. The impairment may last several minutes.
- Afterimage is the perception of spots in the field of vision. This can be distracting and annoying, and may last several minutes, although there have been reports of afterimages lasting several days.
- Glare is a reduction or complete loss of visibility in the central field of vision while being exposed to the direct or scattered beam. This is similar to viewing oncoming headlights on a dark night. Once the beam is out of the field of vision, the glare ceases. While this does not pose a hazard to the eye, it can cause serious distraction. Glare can be exacerbated when the beam is reflected from a mirror-like surface.