The University of Dayton Research Institute

Basic Laser Safety Training

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L.A.S.E.R. is the acronym for LIGHT AMPLIFICATION BY STIMULATED EMISSION OF RADIATION.
Introduction

This presentation is primarily for operators of class 3b and class 4 lasers, which are commonly used in research laboratories.

This presentation includes basic knowledge, safety procedures and hazards associated while working with lasers. Many individuals can still find new ways to hurt themselves with lasers in the lab. Please don’t do this.

Applicable Instructions

> ANSI Z136.1 (Industry Standard)
Program Outline

Elements of the laser safety program

- Laser Terms (...just a few)
- About Lasers
- Types of Lasers: Classifications
- Biological Effects of Lasers
- Warning Signs and Workplace Controls
Elements of the laser safety program (cont’d)

- Beam Hazards
- Non-Beam Hazards
- Personal Protective Equipment
- Authorized Personnel
- Medical Surveillance
Elements of the laser safety program (cont’d)

- Standard Operating Procedures (SOPs)
- Mishap Reporting
- Evaluation Feedback
- Points of Contact
...common laser terms

should – understood as advisory
shall – understood as mandatory
diffuse reflection or transmission – change of the spatial distribution of a beam when it is reflected in many directions by a surface (such as sandblasted metal) or by a medium (such as frosted glass)
specular reflection – a mirror-like reflection (may be nearly as harmful as direct exposure to the beam) could be from jewelry, polished tools etc…
continuous wave laser – a laser operating with a continuous output for a period \( \geq 0.25 \) s
pulsed laser – delivers its energy in the form of a single pulse or a train of pulses (duration of pulse \(< 0.25 \) s)
Q-switched laser - emits short (approx 10-250 ns), high-power pulses by means of a Q-switch (device for producing very short intense laser pulses by enhancing the storage and dumping of electronic energy in and out of the lasing medium, respectively
collecting optics – lenses or optical instruments having magnification and thereby producing an increase in energy or power density (i.e. binoculars, telescopes, microscopes, loupes)
The light emitted from a laser is monochromatic, that is, it is of one color/wavelength. In contrast, ordinary white light is a combination of many colors (or wavelengths) of light.

Lasers emit light that is highly directional, that is, laser light is emitted as a relatively narrow beam in a specific direction. Ordinary light, such as from a light bulb, is emitted in many directions away from the source.

The light from a laser is said to be coherent, which means that the wavelengths of the laser light are in phase in space and time. Ordinary light can be a mixture of many wavelengths.

These three properties of laser light are what can make it more hazardous than ordinary light. Laser light can deposit a lot of energy within a small area.
Incandescent vs. Laser Light

1. Many wavelengths
2. Multidirectional
3. Incoherent

1. Monochromatic
2. Directional
3. Coherent
Basic components of a laser

- **Lasing material or medium**: could be gas (HeNe), liquid, solid (ruby) or semi-conductor (diode).

- **Excitation mechanism or energy source**: can be a flash bulb, arc, another laser or electricity.

- **Optical cavity**: nearly sealed cylinder that uses mirrors to collect, concentrate and produce a coherent beam.
Laser Safety Standards and Hazard Classification

Lasers are classified by hazard potential based upon their optical emission.

Necessary control measures are determined by these classifications.

In this manner, unnecessary restrictions are not placed on the use of many lasers which are engineered to assure safety.

In the U.S., laser classifications are based on American National Standards Institute’s (ANSI) Z136.1 Safe Use of Lasers.
Laser Classifications

The following criteria are used to classify lasers:

1. **Wavelength**. If the laser is designed to emit multiple wavelengths the classification is based on the most hazardous wavelength.

2. For continuous wave (CW) or repetitively pulsed lasers the **average power output** (Watts) and **limiting exposure time** inherent in the design are considered.

3. For pulsed lasers the **total energy per pulse** (Joule), **pulse duration**, **pulse repetition frequency** and **emergent beam radiant exposure** are considered.
ANSI Classifications

**Class 1** - denotes laser or laser systems that do not, under normal operating conditions, pose a hazard.

**Class 2** - denotes low-power visible lasers or laser system which, because of the normal human aversion response (i.e., blinking, eye movement, etc.), do not normally present a hazard, but may present some potential for hazard if viewed directly for extended periods of time (like many conventional light sources). Lasers in this class emit 1mW or less.
ANSI Classifications (cont’d)

• **Class 3a** denotes some lasers or laser systems having a CAUTION label that normally would not injure the eye if viewed for only momentary periods (within the aversion response period) with the unaided eye, but may present a greater hazard if viewed using collecting optics. Class 3a lasers have DANGER labels and are capable of exceeding permissible exposure levels. If operated with care Class 3a lasers pose a low risk of injury.

• **Class 3b** denotes lasers or laser systems that can produce a hazard if viewed directly. This includes intrabeam viewing of specular reflections. Normally, Class 3b lasers will not produce a hazardous diffuse reflection.

• **Class 4** denotes lasers and laser systems that produce a hazard not only from direct or specular reflections, but may also produce significant skin hazards as well as fire hazards.
Types of Laser Hazards

1. **Eye**: Acute exposure of the eye to lasers of certain wavelengths and power can cause corneal or retinal burns (or both). Chronic exposure to excessive levels may cause corneal or lenticular opacities (cataracts) or retinal injury.

2. **Skin**: Acute exposure to high levels of optical radiation may cause skin burns; while carcinogenesis may occur for ultraviolet wavelengths (290-320 nm).

3. **Chemical**: Some lasers require hazardous or toxic substances to operate (i.e., chemical, dye, Excimer lasers).

4. **Electrical**: Most lasers utilize high voltages that can be lethal. This is the most common source of serious laser related injuries.

5. **Fire**: The solvents used in dye lasers are flammable. High voltage pulse or flash lamps may cause ignition. Flammable materials may be ignited by direct beams or specular reflections from high power continuous wave (CW) lasers.
Lasers and Eyes

What are the effects of laser energy on the eye?

- Laser light in the visible to near infrared spectrum (i.e., 400 - 1400 nm) can cause damage to the retina resulting in scotoma (blind spot in the fovea). This wave band is also known as the "retinal hazard region".

- Laser light in the ultraviolet (290 - 400 nm) or far infrared (1400 - 10,600 nm) spectrum can cause damage to the cornea and/or to the lens.

Photoacoustic retinal damage may be associated with an audible "pop" at the time of exposure. Visual disorientation due to retinal damage may not be apparent to the operator until considerable thermal damage has occurred.
Symptoms of Laser Eye Injuries

- Exposure to the invisible **carbon dioxide laser** beam (10,600 nm) can be detected by a burning pain at the site of exposure on the cornea or sclera.

- Exposure to a visible laser beam can be detected by a bright color flash of the emitted wavelength and an after-image of its complementary color (e.g., a green 532 nm laser light would produce a green flash followed by a red after-image).

  *The site of damage depends on the wavelength of the incident or reflected laser beam:*

- When the retina is affected, there may be difficulty in detecting blue or green colors secondary to cone damage, and pigmentation of the retina may be detected.

- Exposure to the **Q-switched Nd:YAG laser** beam (1064 nm) is especially hazardous and may initially go undetected because the beam is invisible and the retina lacks pain sensory nerves.
Skin Hazards

- Exposure of the skin to high power laser beams (1 or more watts) can cause burns. At the under five watt level, the heat from the laser beam will cause a flinch reaction before any serious damage occurs. The sensation is similar to touching any hot object, you tend to pull your hand away or drop it before any major damage occurs.

- With higher power lasers, a burn can occur even though the flinch reaction may rapidly pull the affected skin out of the beam. These burns can be quite painful as the affected skin can be cooked, and forms a hard lesion that takes considerable time to heal.

- Ultraviolet laser wavelengths may also lead to skin carcinogenesis.
Other Hazards Associated with Lasers

Chemical Hazards
Some materials used in lasers (i.e., excimer (fluorine gas tanks), dye and chemical lasers) may be hazardous and/or contain toxic substances. In addition, laser induced reactions can release hazardous particulate and gaseous products.

Electrical Hazards
Most common non-beam hazard. Lethal electrical hazards may be present in all lasers, particularly in high-power laser systems.

Secondary Hazards including:
• excessive noise from very high energy lasers
• X radiation from faulty high-voltage (>15kV) power supplies
• explosions from faulty optical pumps and lamps
• fire hazards
Laser Exposure Limits—Terminology

–**Maximum Permissible Exposure** (MPE):
  MPE is defined in ANSI Z-136.1"The level of laser radiation to which a person may be exposed without hazardous effect or adverse biological changes in the eye or skin."
  
  For most of you it means the room where the laser is located is considered inside the MPE area.

–**Nominal Ocular Hazard Distance** (NOHD):
  The distance from the laser where the beam is not expected to exceed the MPE.

–**Nominal Hazard Zone** (NOZ):
  The area within which the MPE is equalled or exceeded.
Nominal Hazard Zone (NOZ):
In many research applications open beams are required, making it necessary to define an area of potentially hazardous laser radiation. This area is called the nominal hazard zone (NHZ) which is defined as a space within which the level of direct, scattered, or reflected laser radiation exceeds the MPE. The purpose of a NHZ is to define an area in which control measures are required.
Safety CONTROL MEASURES

**Engineering Controls**

- Interlocks
- Beam Enclosures
- Shutter
- Attenuators

**Personnel Protective Equipment (PPE)**

- Eye Protection
- Gloves and Clothing for Chemicals and UV

**Administrative Controls**

- Standard Operating Procedures (SOP’s)
- Training
- Warning Signs and Labels
**Specular reflections** are mirror-like reflections and can reflect close to 100% of the incident light. Flat surfaces will not change a fixed beam diameter only the direction. Convex surfaces will cause beam spreading, and concave surfaces will make the beam converge.

**Diffuse reflections** result when surface irregularities scatter light in all directions. The specular nature of a surface is dependent upon the wavelength of incident radiation. A specular surface is one that has a surface roughness less than the wavelength of the incident light.

A very rough surface is not specular to visible light but might be to IR radiation of 10.6 µm from a CO2 laser.
Engineering Controls

Eliminating beam reflections:
(whenever possible remove all reflective materials from within the NOHD and preferably from the room.)

- Remove mirrors and other brightly polished objects from the room; also avoid glossy paints and finishes.

- Remove all jewelry including watches.

- Use non-reflective materials and supplies.
Beam Stops/Shutters: Use when tuning the laser and to prevent stray beams from leaving the optics bench or workspace.

- specially designed laser barriers or curtains which can withstand either direct and/or diffusely scattered beams

- flammability is an important consideration
  – the material cannot support combustion or be consumed by flames during and at the termination of the laser

- also ensure decomposition products do not create a new hazard
Laser glasses or goggles:

**Mandatory: use with all procedures.**

- Laser specific (i.e. optical density & wavelength labeling is required). Do not use with other types of lasers.

- Check laser goggles/glasses periodically for cracks, scratches, pitting – dispose of eyewear if found to be damaged or defective

- Handle laser eyewear carefully; replacements are expensive
Skin Protection:
- appropriate gloves and/or clothing is sufficient for lasers requiring skin protection
- sunscreen (wipes off or comes off with sweat) is not recommended for UV systems

* for extremely high-powered lasers, there is no protection available for direct exposure –

Inaccessibility is the only answer;
The beam must be enclosed
Non-beam Hazards

**Physical** (non-beam)
- Flammable chemicals/solvents
- Collateral radiation (electronic product radiation from operation)
- Electrical hazards and controls, this is the major source of serious laser related injuries (shock, electrocution)
- Fire hazards and controls
- Explosion and controls
- Plasma radiation (aka plume radiation)

**Chemical**
- Laser generated airborne contaminants, from material processing or interacting with beam stops.
- Compressed gases
- Dyes and solvents
Laser Eye Exam

To establish a baseline of visual acuity and ocular “health”.

For Whom:
- All laser operators and/or anyone assisting, maintenance personnel
  and any individual (as part of their job) who may be exposed to laser radiation.

What’s Involved:
- Visual acuity and fundoscopic examination of your eyes along with a very brief medical history.
Laser Eye Exam (cont’d)

You are responsible for making your own appointment and providing a purchase request to the eye center to pay for the exam.

Where To Go:

Allied Eye Physicians
5250 Far Hills Ave #207
Dayton, Ohio 45429
937-433-2300

Location Map

How Often:

-Currently UDRI requires a baseline and termination exam. Also, an exam immediately following any laser mishap.