Boston University

Laser Safety Training for users of Class 3B or 4 Lasers
Laser Safety Training is offered on line via RIMS and supplemented by your Permit Holder or Laboratory Manager on specific laser systems.

All Permit Holders and Users are required to complete initial on-line training and refresher training every TWO years.

Training is available by the Laser Safety Officer if requested.

The following slide presentation is used for educational purposes.
Ma-DPH Broad scope Medical License
Ionizing Radiation & Non-Ionizing Radiation

MA-DPH 120 CMR 105

ANSI- Z 136.1 2014

ANSI-Z 136.3 2011

Boston University, BUMC, BMC is granted a license by the MA-DPH.

The Laser Safety Subcommittee (LSSC) observes the MA-DPH regulations and ANSI standards and federal guidelines.

MA-DPH regulates the use of non-ionizing radiation (i.e. lasers)
FUNDAMENTALS OF LASER OPERATION
Basic Laser Safety

What is a Laser?

- Light
- Amplification by
- Stimulated
- Emission of
- Radiation

- The energy generated by a laser is in or near the optical portion of the electromagnetic spectrum
Properties of Laser Radiation

- **Monochromatic** - all light produced by the laser is of one wavelength or color. Exceptions include multiline gas lasers and new white-light lasers.  
  ex. Nd:YAG (532,1064nm)

- **Directional** - collimated (divergence~1mRad) photons traveling in the same direction

- **Coherent** - all peaks of sinusoidal waves (photon) are in phase with each other

*Lasers pose more hazard than ordinary light because energy is focused into a small area*
Types of Laser

- Continuous Wave (CW) – operates as a continuous output for a period > 0.25 seconds

- Pulsed Laser – delivers energy in single pulses with a duration of less than 0.25 seconds

- Q-switched laser – emits short (10 ns – 250 ns) high-power pulses by means of a Q-switch
Laser Components

Active Medium
- Solid State-operate in pulsed or continuous wave (CW) mode
- Semiconductor
- Gas - CW CO2, Argon, HeNe, Excimer
- Liquid (dye) (CW or pulsed)

Excitation Mechanism
- Optical
- Electrical
- Chemical

Optical Resonator
- Mirror
- Partially reflective mirror

Semiconductor (Diode)
- GaAlAs - 750-950nm range
- InGaAsP (Indium Phosphate 1100-1650 nm)
The optical spectrum

Laser light is nonionizing and ranges from the:

- ultra-violet (100 - 400nm)
- visible (400 - 700nm), and
- infrared (700nm - 1mm).
BIOEFFECTS OF LASER RADIATION ON THE EYE AND SKIN
EYE

- Light rays enter the eye through the cornea (the clear front “window” of the eye). Light is refracted by the cornea and the bent rays pass through the pupil, the opening in the center of the iris, through which light enters the eye.

- Light rays pass through the on the retina.

Information from How Does the Human Eye Work? [https://www.nkcf.org/how-the-human-eye-works/]
Eye Anatomy

[Diagram of the eye with labeled parts: Sclera, Choroid, Retina, Macula, Fovea, Vitreous, Lens, Ciliary Body, Ciliary Muscle, Aqueous Humor, Cornea, Pupil, Iris, Zonules, Optic Disc, Optic Nerve]
Retinal Injury

- Photoretinitis: Photochemical effect from duration of greater than 10 seconds and intense exposure to laser wavelengths from 400 – 500 nm
- Retinal burns: Photocoagulation of retina by brief (pulsed) and intense exposure to laser radiation between 400 – 1400 nm
- Photo disruption of Retina: Retinal hemorrhage from q-switched laser pulse
- Visual Effect: Scotoma – blind spot in the visual field

Retinal damage can cause permanent loss of vision
Corneal Injury

- Photo keratitis: Welder’s Flash or snow blindness – photochemical effect on corneal epithelium by UVB/UVC laser radiation
- Corneal Burns: thermal effect on corneal epithelium by IRB or IRC laser radiation
- Superficial Injury: lesion clears in 24 – 48 hours
- Deep Burns: penetrating burns that produce permanent damage – corneal transplant for repair may be required
Each number represents a laser hit to the vitreous and in close proximity to the retina.
Skin Photochemical and Thermal Burns

- Ultraviolet (UV) Sunburn: erythema: skin reddening caused by photochemical effect on skin epithelium by UVB or UVC laser radiation

- UV Delayed Effects: accelerated skin aging/skin cancer

- Thermal Skin Burns: typically from IR laser radiation, thermal effect on skin epithelium.

- High powered (Class 4) lasers, can burn the skin and set clothes or flammable objects in the optical path on fire.
## Potential Biological Laser Effects*

<table>
<thead>
<tr>
<th>Band</th>
<th>Wavelength (nm)</th>
<th>Eye</th>
<th>Skin</th>
</tr>
</thead>
<tbody>
<tr>
<td>UV-C</td>
<td>200-280</td>
<td>Corneal burn</td>
<td>Erythema (sunburn), skin cancer</td>
</tr>
<tr>
<td>UV-B</td>
<td>280-315</td>
<td>Corneal burn</td>
<td>Accelerated skin aging, pigmentation</td>
</tr>
<tr>
<td>UV-A</td>
<td>315-400</td>
<td>Photochemical cataract</td>
<td>Pigmentation darkening, photosensitive reaction, skin burn</td>
</tr>
<tr>
<td>Visible</td>
<td>400-780</td>
<td>Photochemical and thermal retinal injury</td>
<td>Photosensitive reaction, skin burn</td>
</tr>
<tr>
<td>IR-A</td>
<td>780-1400</td>
<td>Cataract, retinal burn</td>
<td>Skin burn</td>
</tr>
<tr>
<td>IR-B</td>
<td>1400-3000</td>
<td>Corneal burn, aqueous flare, possibly cataract</td>
<td>Skin burn</td>
</tr>
<tr>
<td>IR-C</td>
<td>3000-1 mm</td>
<td>Corneal Burn</td>
<td>Skin burn</td>
</tr>
</tbody>
</table>

*Information from Reed College: [https://www.reed.edu/ehs/Laser_Safety/4laser_effects.html](https://www.reed.edu/ehs/Laser_Safety/4laser_effects.html)
SIGNIFICANCE OF SPECULAR AND DIFFUSE REFLECTIONS
Diffuse or Specular?

**Specular** – Smooth surfaces irregularities or roughness are < the incident light wavelength. Light reflect at a definite angle

**Diffuse** – Surface irregularities or roughness are > the incident light wavelength. Light is scattered in all directions
Not all viewing conditions are the same

Specular reflection          Convex reflector          Concave reflector

Diffuse reflection
Commonly Used Laser Operating Parameters

- **Power*** – the rate at which energy emitted from a laser (expressed in units of Watts)

- **Beam diameter**** – distance across the center of the beam such that the irradiance (intensity) is $1/e^2$ of the maximum irradiance

- **Spot size**** – the radial distance from the center point of maximum irradiance to the $1/e^2$ point.

- **Power Density (irradiance)*** - The amount of incident laser power on a unit surface area (expressed as Watts/cm²)

* Referenced from Definitions in Laser Technology
  [http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2840918/](http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2840918/)

** Referenced from Laser beam divergence and spot size:
  [http://vlab.amrita.edu/?sub=1&brch=189&sim=342&cnt=1](http://vlab.amrita.edu/?sub=1&brch=189&sim=342&cnt=1)

More information on lasers can be found at
  [https://www.osha.gov/dts/osta/otm/otm_iii/otm_iii_6.html#1](https://www.osha.gov/dts/osta/otm/otm_iii/otm_iii_6.html#1)
Light Interaction

Objects tend to selectively absorb, reflect, or transmit light of certain frequencies

- **Absorption** – transformation of radiant power to another type of energy, typically heat
- **Reflection** -those wavelengths not absorbed or transmitted
- **Transmission** – passage of electromagnetic radiation through a medium
- **Diffusion (scattering)** – deflecting unidirectional beams into many directions
- **Laser-induced fluorescence (LIF)** – optical emission from molecules excited to higher energy levels by the absorption of electromagnetic radiation

** Definition of Laser-induced fluorescence: [http://www.chemicool.com/definition/laser_induced_fluorescence.html](http://www.chemicool.com/definition/laser_induced_fluorescence.html)
NON-BEAM HAZARDS OF LASERS
Recognize hazard potential to eliminate potential disasters:

- Blindness
- Burns
- Fire
- Death
Electrical Hazards-Non Beam Hazards

- Inspect cords, cables, and plugs
- Improperly insulated electrical terminals
- Excessive wires and cables on floor (trip hazard)
- Equipment inspection certification
Basic Laser Safety - Non-Beam Hazards

Chemical
Dye lasers
Gases from laser operations

Optical
UV from laser welding
UV from discharge tubes and pumping

Fire/Explosion
Ignition of gases and/or vapors
Electrical wiring and capacitor banks
Laser Gas Air Contaminates (LGAC)

Laser plume may contain biological entities, carcinogens, fine dust mutagen, irritants, metal oxides, etc.

Effective Controls

- Safe work practice
- Ventilation system with exhaust to the outside air (HEPA filter)

*If you are working with Biological and/or Chemicals with your laser system that might involve substances becoming airborne, contact the LSO at 617-638-7052
LASER AND LASER SYSTEM CLASSIFICATIONS
Laser Classification

- **Class 1** - is safe under all conditions of normal use. This means the maximum permissible exposure (MPE) cannot be exceeded.

- **Class 1M** - is safe for all conditions of use except when passed through magnifying optics such as microscopes and telescopes. Class 1M lasers have a total output power is below class 3B but the power that can pass through the pupil of the eye is within Class 1. Class 1M lasers produce large-diameter beams, or beams that are divergent.

NOTE: The MPE for a Class 1M laser cannot normally be exceeded unless focusing or imaging optics are used to narrow the beam. If the beam is refocused, the hazard of Class 1M lasers may be increased and the product class may be changed. Please verify with the laser safety officer if your application narrows a Class 1M beam.
Laser Classification

- **Class 2** - is safe because the blink reflex will limit the exposure to no more than 0.25 seconds. It only applies to visible-light lasers (400–700 nm). Class 2 lasers are limited to 1 mW continuous wave, or more if the emission time is less than 0.25 seconds or if the light is not spatially coherent.

NOTE: Intentional suppression of the blink reflex could lead to eye injury.

- **Class 2M** - A Class 2M laser is safe because of the blink reflex if not viewed through optical instruments. As with class 1M, this applies to laser beams with a large diameter or large divergence, for which the amount of light passing through the pupil cannot exceed the limits for Class 2.
Laser Classification

- **Class 3R** - is considered safe if handled carefully, with restricted beam viewing. With a class 3R laser, the MPE can be exceeded, but with a low risk of injury. Visible continuous lasers in Class 3R are limited to 5 mW. For other wavelengths and for pulsed lasers, other limits apply.

- **Class 3B** - is hazardous if the eye is exposed directly, or reflected but diffuse reflections such as from paper or other matte surfaces are not harmful. Continuous lasers in the wavelength range from 315 nm to far infrared are limited to 0.5 W. For pulsed lasers between 400 and 700 nm, the limit is 30 mW. Other limits apply to other wavelengths and to ultra short lasers. Protective eyewear is required where direct viewing of a class 3B laser beam may occur. Class-3B lasers must be equipped with a safety interlock.
Laser Classification

Class 4 - can burn the skin, in addition to potentially devastating and permanent eye damage as a result of direct or diffuse beam viewing. These lasers may ignite combustible materials, and thus may represent a fire risk. Class 4 lasers include all lasers with beam power greater than class 3B. They must be equipped with a safety interlock and require administrative and engineering controls. Most industrial, scientific, military, and medical lasers are in this category.
CONTROL MEASURES
Basic Laser Safety - Exposure Limits

- **MPE (Maximum Permissible Exposure):** the highest laser energy exposure for eye or skin for a given laser that will not cause injury

- **NHZ (Nominal Hazard Zone):** Area within which the MPE can be met or exceeded
Laser Operation and Eye Exposure

- Always *think* before doing, when aligning laser/optical systems
- Follow the SOP and beam alignment procedures (class 3B and 4)
- Only approved users after specific training from the Permit Holder may align lasers.
- KEEP THE LIGHTS ON
- Smaller iris lets-through less light
- Don’t do involved alignment in an overly-fatigued state
- Beam block when inserting new optical elements
- Be aware of lens and mirror surface reflections
Laser Eye Wear

- Optical Density (OD) is the transmission of light through a highly blocking optical filter.
- Only use laser eye protection specifically labeled for the type of laser used.
- Lens color is not an indication of wavelength or OD protection.
- OD and specific wavelengths is usually on the front of goggles.
- Use viewing devices (IR viewer) that will allow visualization of the beam without being exposed to any laser.
- Do not mix non-laser eyewear in the laser storage rack.
Basic Laser Safety - Safety Controls

Administrative and Procedural: organizational and procedural aspects of laser safety

Administrative Controls
- Warning Signs
- Labels
- SOPs- Class 3B and 4 laser systems
- Training
- Security
- SOP’s
- Standard Operating Procedures (SOP)

- Training
- Credentialing requirements
- Procurement and Registration of Class 3B and 4 lasers
- Incident reports
- Inspections
- Identify the NHZ
- Servicing
Basic Laser Safety - Safety Controls

Engineering Controls

- Beam Housings
- Shutters
- Beam Blocks
- Attenuators
- Remote viewing devices
- Interlocks/switch lock receptacles
- Emergency Disconnects
Optical protection: practical tips for laser operators

- **REMOVE** jewelry, especially watches and rings to avoid reflection and other reflective material from your body

- **Most incidents occur during alignment** Avoid using reflective tools in alignment

- **Monitor** all reflection from optics in the setup

- Close eyes when bowing through plane of laser table – i.e. picking up a dropped tool

- **Communicate** with other lab operators, when performing high-risk tasks

- **Wear** laser safety glasses or goggles when appropriate
EYE SAFETY

- Avoid “eye level” beams
- Avoid situations where the beam is, or might be deflected upward i.e. beam steering, “flippers,” periscopes
- Use beam blocks
- Exercise caution when leaning down to beam-level
- Always look away from table area when bending-down
- Think twice before leaning to table level to get a better look at your experiment
- Be VERY CAUTIOUS using “IR cards” and Ultraviolet (UV) Sensor Cards
Beam Alignments

The majority of accidents occur during beam alignments.

Common scenario: unanticipated reflection from an optic when you are

• Not wearing any protective eyewear „
• Wearing inappropriate eyewear „
• Using the wrong OD „
• Wearing low-OD alignment eyewear with operational power levels „
• Wearing high-OD operational eyewear with low-power (alignment) power levels„
• Using multiple wavelengths and there is a wavelength compatibility problem with your eye wear

Beam alignment procedures are REQUIRED for all class 3B & 4 laser setups and must be submitted to LSSC for approvals

Read all procedures
Basic Laser Safety - Accidents

Common Causes of Accidents

- Accidental energization or firing of laser
- Bypass of Interlocks
- Beam Alignment
- Grounding
- No laser eye wear
- Movement of beam path
- Reflective objects in beam path (clutter)
  - CALL 617-638-7052 (BUMC) (8am-5pm)
    - 24 hrs. call control 617-638-4144
      - 617-353-7233 (CRC)

Contact your Permit Holder and ROHP
OVERALL RESPONSIBILITIES OF MANAGEMENT AND EMPLOYEES
Laser Safety Sub-Committee (LSSC)

- Sub-committee of the Radiation Safety Committee (RSC).

- That has the authority to approve/suspend research and health care laser systems privileges.

- The LSSC meets quarterly and the RSC gives final approval to LSC operations.
Laser Safety at Boston University

Laser Safety Officer (LSO)

- ANSI Z136.1 specifies that any facility using Class 3b or Class 4 lasers or laser systems should designate a Laser Safety Officer to oversee safety for all operational, maintenance, and servicing situations.

- This person should have the authority and responsibility to monitor and enforce the control of laser hazards. This person is also responsible for the evaluation of laser hazards and the establishment of appropriate control measures.
Elements of BU Laser Safety Program

- **Laser Safety Sub Committee**
  - Equipment Registration for class 3B and 4 lasers
  - Personnel Registration and Training
  - SOP’s for 3B and 4 lasers
  - Signage
  - Emergency Procedures
  - Inspections and Monitoring

- **Laser Permit Holder typically the PI or lab manager (for a shared facility) approved by LSSC**
  - Train Users
  - Writes SOP’s
  - Oversees beam alignment (only trained user by Permit Holder)
  - Allow only authorized users to enter hazard areas
  - Establish experimental condition for use
  - Address non-beam hazards
  - Post emergency numbers and procedures
Elements of BU Laser Safety Program

Laser Supervisor Roles
- Established SOP for laboratory
- Approved on Permit Holder
- Accountability of laser radiation workers, laser devices & associated equipment registered with the Laser Safety Officer.
- Maintain a safe environment for personnel
- Maintain daily operations in laser laboratory.
- Reports any equipment malfunction or potential hazard

Laser Users Role
- Receive training from laser supervisor before beginning work with lasers
- Follow SOP
- Wear appropriate eyewear and PPE
- Use minimum power required/reduce output with attenuators
- Keep beam path away from eye level
- Remove unnecessary objects/tools from table
Educated Safe Employee

- Provides adequate laser awareness for others
- Committed to BU policies and regulatory compliance
- Practices safe methods & procedures to eliminate Maximum Permissible Exposure (MPE) to the eye or skin
Summary

- Permits issued to Permit Holder (PH) by LSSC
- All Class 3B and 4 laser systems must be registered with the LSO
- All Class 3B and 4 laser systems users must have SOP’s, alignment procedures, user registration, user certifications, eye-ware and safety controls in place.
- See our web site for all forms at: http://www.bu.edu/ehs/programs/laser-safety/
- Notify the LSO of all new laser purchases, intended disposal, transfers of laser systems, construction or renovations.
References

6. 105 CMR 121.000, Massachusetts Department of Public Health, To Control the Radiation Hazards of Lasers, Lasers Systems and Optical Fiber Communications Systems Utilizing Laser Diode or Light Emitting Diode Sources.
8. OSHA General Duty Clause of Public Law 91-59
9. 21 CFR 1040.
QUIZ

For completion of your laser safety training you must pass the laser safety quiz.

Additional laser training is provided by your permit holder on specific laser systems.

If you have any questions, contact the Laser Safety Officer at 617-638-7052.

A passing grade of 80 percent is required.
Contacting Laser Safety

BUMC

- Week Day Phone: Radiation Safety Office
  617-638-7052 (8am-5pm)
- Emergency **OFF Hours** call RPO telephone or Page-Control at 617-638-4144 for additional assistance

Charles River Campus (CRC)

- 617-353-7233 (3-SAFE) or call Public Safety at 617-353-2110; 617-353-2121 (emergencies only)

24-**hrs.** a day there is a staff on call and emergency assistance is available