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Environmental Health & Safety

Radiation – Non-ionizing

This Design Guide applies to all facilities, including leased properties. All facilities utilizing non-ionizing, such as lasers, superconducting magnets, radio frequency and microwave, artificial ultraviolet radiation, and light-emitting diodes (LEDs) must meet all federal and/or local regulatory requirements. References are provided at the end of this chapter.

General Safety Requirements:

a. Laboratories using non-ionizing radiation sources (such as: lasers, ultraviolet lights, and large magnets) should be designed to minimize radiation exposure to personnel and the environment.
b. Laboratory designs shall utilize appropriate engineering and administrative controls to prevent radiation exposure in excess of the applicable regulations, standards, and guidelines.
c. Laboratory designs should be forwarded to the UW Radiation Safety Office (RSO) for non-ionizing radiation safety review and approval prior to being released for bid or beginning construction (for internal projects that are not put up for bid).
d. Consideration should be given to having all facilities/laboratory door access controlled by card proximity readers. The doors must remain locked at all times, and access would be granted only to persons associated with the space and trained according to the EH&S training requirements.

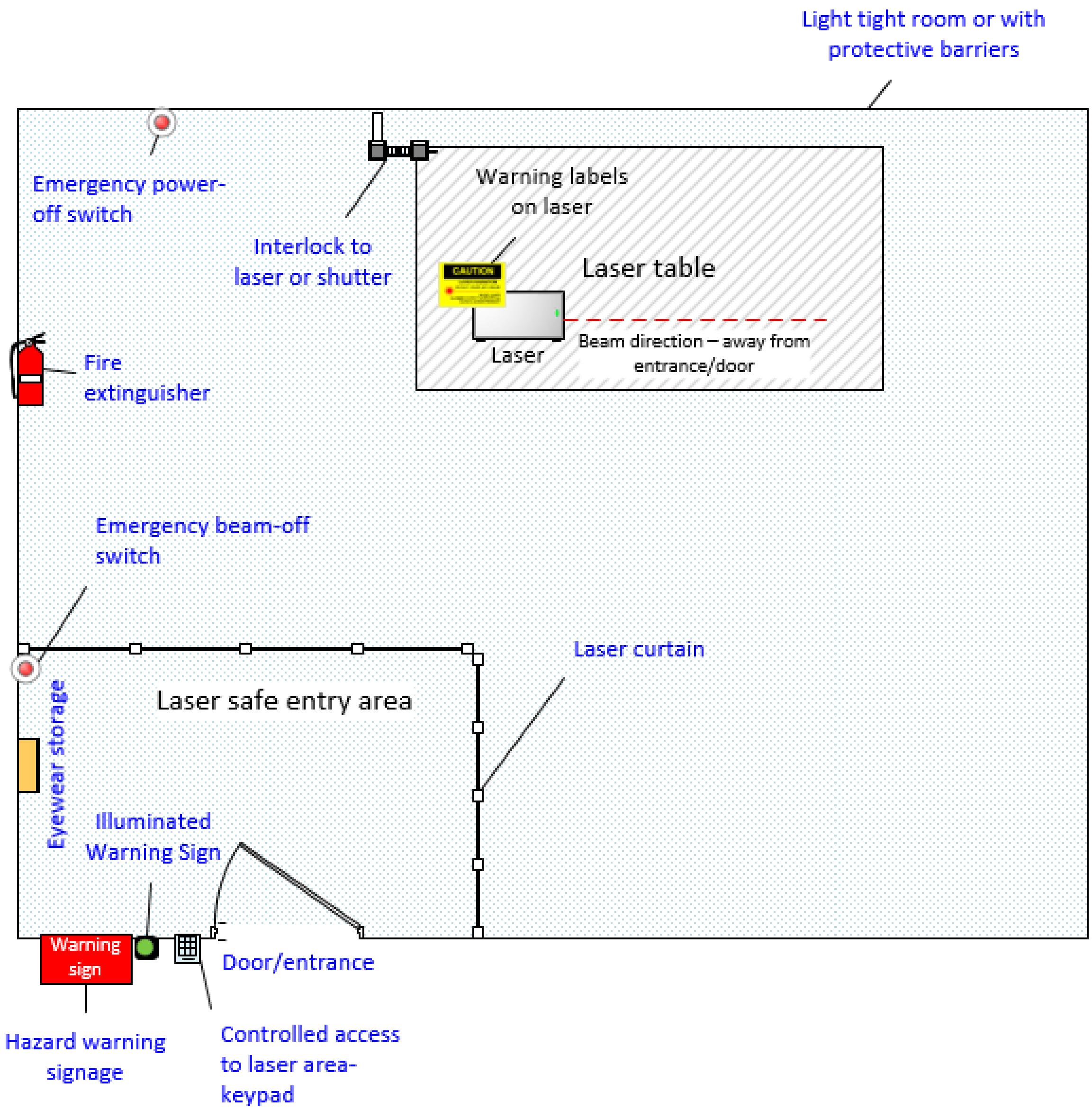
1. Laser Facilities

This section provides general design and engineering guidance for the development and installation of safety controls in facilities containing Class 3B and Class 4 laser systems. This guide does not apply to clinic use lasers.

The responsible Principal Laser Users for each Class 4 system should incorporate as many of these design features as applicable and appropriate into their laboratories or facilities. Please work with EH&S Laser Safety Officer to achieve the same level of protection with alternate control measures.

An example of safety control measures for laser facilities is shown in Figure 1.

Figure 1: Laser Lab Template



Access Control/Controlled Entry

Class 3B & Class 4 laser labs require access control. The three most common controls are:

- Door interlock systems
- Electronic lock (keypad/RFID)
- Hazard warning posting

a. <u>Door interlock systems</u>

- Interlock on entry door(s) wired to activate the shutter upon opening of the door into the laser use area; those doors without a curtained entryway enclosure must be equipped with a non-defeatable interlock system
- Doors protected by a curtained enclosure must have either a non-defeatable or a defeatable interlock system (i.e., bypass switch allows trained individuals to temporarily bypass the interlock when entering or exiting)
- The interlock must be armed to allow the laser to be turned on
- Non-defeatable door interlock is not a viable option. This type of system is designed to block the beam or drop power every time the door is opened.
- Defeatable door interlock is set with an access device on the outside (i.e., key pad or card key reader) that allows authorized staff to enter. Triggering the device sets a predetermined (15-30 second) bypass where the door can be open and the laser will stay on. Exiting is best controlled by a crash bar which triggers a pre-timed bypass.

  Standard door safety requirements:

  - Door must be self-closing,
  - Standard keyed lock is not recommended,
  - Doors to lab should not be fire-rated unless necessary,
  - Fire resistant doors should have magnetic hold-open features,
  - Door will close in event of an alarm,
  - Door must be light tight,
  - If double door, a protective strip must be installed covering the space between the doors.

  Egress doors:

  - Crash-bar for easy egress,
  - 36” or 42” wide doors,
  - Doors opening onto exit corridors must swing with exit egress,
  - Minimum clearance if 32” when door is open 90 degrees,
  - Lab benches, equipment, furniture, etc. cannot be placed within 5’ of egress,
  - Doors within interior partitions must be self-latching.

b. <u>Electronic lock (keypad/RFID)</u>

- RFID card access or Cipher lock with key override: this approach provides secure access but has no effect on laser operation. The key override is for first responders only, not housekeeping.

c. <u>Hazard warning posting</u>

- Posting of hazard warning can only be allowed if the Class 3B or Class 4 laser system is in normal operation operating in a Class 1 or near Class 1 system configuration. Example: Confocal microscopes.
- All Class 3B and Class 4 is required to have a hazard communication posting. The below information is required for ANSI warning sign:
    - Highest class laser in use,
    - Signal word (Warning or Danger),
    - Wavelengths in use,
    - Optical Density for wavelengths,
    - Alert of hazards and instruction on entry (if there is no laser safe entry area),
    - Emergency contact numbers.

  This ANSI laser hazard communication sign can be obtained from the EH&S Laser Safety Officer.

Illuminated Warning Sign

A lighted laser sign outside each entryway to the laser controlled is required. The lighted sign must illuminate only when the laser system is operating. Signs should be mounted so as to be visible both at the doorway and at eye height level. **The lighted sign must be interlocked to the laser power supply or a laser shutter**.

<u>Sign requirements</u>:

- Posted at eye level (60” or 152 cm above the floor) to the side of the entryway, not above the door frame,
- LED light source,
- A red light or non-descriptive sign is not sufficient,
- The illuminated sign is required for each doorway that is accessible,
- Illuminated whenever the laser is energized and capable of producing a beam,
- Automatic light, light turn off/on based on when the laser is on/off,
- If light manually controlled, light switch shall be located in a convenient position near the laser control.

Windows

Windows around the laser labs should be avoided as they will need to be covered. If doors are equipped with windows, the following must be considered:

- Window panels in doors should be covered with a permanent opaque material,
- If windows are required for non-laser use periods, then shades or removable covers for laser operation need to be available,
- Electronic shutter windows can be used in some circumstances,
- Windows can be covered with optical density acrylics to provide protection and viewing.
- Such acrylics must be labeled with wavelength and optical density,
- Portals/viewing windows must be designed to prevent any exposure above the maximum permissible exposure value. Contact EH&S Radiation Safety for support with this evaluation,
- Wall windows should be treated the same as door windows.

Protective Eyewear Storage

The laser protective eyewear can be stored inside or outside the laser use area, or at both locations. Storage shelf or rack must protect the physical integrity of the eyewear and be easily accessible to the users.

<u>Storage Considerations:</u>

- If multiple lasers are present, store in a way to avoid confusing different types of eyewear,
- Laser protective eyewear can be stored in the typical “cubby-hole” or “mailbox” type of storage rack.

Emergency Crash-Off Switches

For emergency conditions, there shall be a clearly marked Emergency Stop/Kill Button for deactivating the laser or reducing the output to levels at or below the appropriate safety level.

- An emergency beam off switch that activates the beam shutter shall be located near the laser system or inside/outside the laser safe curtain area.
- For laboratories containing high voltage or high current devices, an emergency power-off button which cuts electrical service to high power equipment in case of electrical emergency must be located at an easily accessible point within the laboratory.

Laser safe entry area/curtained enclosure

The purpose of a laser safe entry area/curtained enclosure is to protect the doorway from direct/stray beams (eye-safe areas of the room). These curtains should have the following properties:

- Allow enough room for people entering to put on eye protection,
- No line of sight between room entrance/eye-safe areas to optics/laser
- Hang from track with rollers without blocking sprinkler patterns, and extend from the floor to the ceiling
- Shall not interfere with fire sprinklers
- Curtain systems should consider local fire code requirements and at a minimum meet the requirements of NFPA 701 and ANSI Z136-2014. Fabric should be fire resistant:
  - Prevent combustion when hit by enclosed laser beam
  - Shall not off-gas
  - Shall be flame-retardant/flameproof/laser-rated and rating should be labeled on the curtain.
- Fire detection systems coverage should be considered
- Curtain overlap should be 12" for vertical curtain pieces or have a closure device
- In addition, the laser safety curtain area shall contain:
  - Laser Protective Eyewear Storage (if inside the room)
  - Emergency beam-off and/or power-off switch installed near entrance of lab to turn off laser remotely or activate beam shutter.

Walls/Barriers/Enclosures

Depending on the layout and experiment set up, there are several means of beam containment available to the user. One is to install walls around the set up. This type of enclosure needs to be at least several inches higher than intended beam path. Examples of enclosures and barriers:

a. Perimeter guard such as plastic laser enclosures or covers (must be rated for your wavelength and required optical density) and metal laser enclosures or covers (with diffuse pattern on the inside surface).
b. Complete table barriers - these units are 80/20 frames or uni-strut that stand a few inches off from the optical table and have a track for panels (most commonly sliding panels). Frame can be equipped with HEPA Filters, lights, or no roof at all.
   i. Can be installed around the entire table or portion of it.
   ii. Open or closed on top
   iii. May need task lighting

- Walls should be painted a non-reflective color such as a matte black. There should be no reflective materials in the lab such as corner protectors on walls.
- For open beam, Class 4 labs without any localized barriers such as laser curtains or laser table barriers, the design of a laser-safe entry area must be considered to prevent contact with a stray laser beam upon entrance to the lab. A laser safety eyewear storage rack should be included in this area.

Fire Safety for Lasers

Class 4 laser beams represent a fire hazard. All flammable/combustible construction materials shall be avoided in spaces housing Class 4 lasers. Materials used for beam stops or beam barriers shall not off-gas or be combustible at the beam power used. In situations where flammable compounds and substances exist, it is possible that fires can be initiated by Class 3B lasers.

As a guideline, lasers with powers greater than 10 Watts or with irradiances greater than 10 Wcm-2 have the potential to create fire if misaligned.

For fire safety, these should be available in the laser labs:

- Smoke detector
- Sprinkler heads
  - Additional ones if there is gas use
- Fire extinguishers
  - Should be conspicuously labeled, particularly if recessed
  - Appropriate for chemicals/equipment in use and should be placed near the entrance of each lab, mechanical, electrical room
  - Carbon Dioxide fire extinguishers rather than dry chemical extinguishers
- Fire alarm annunciators

Electrical and Conduit

Appropriate grounding connections shall be provided for laser power supplies and other electrical components. To facilitate use, all grounding connections should be properly marked. Electrical systems shall be marked to show voltage, frequency, and power output. All high voltage sources shall be properly marked and secured to prevent accidental access.

Wiring channels should be run for interlock controls and remote firing/monitoring if applicable. If lasers are to be transported via fiber optics, a separate conduit should be made with appropriate labeling.

Laser Optical Bench

Optical benches shall be secured to prevent severe movements in an earthquake. This requires anchoring a sturdy frame to the laboratory floor that surrounds and is close to (within one-half inch), but not touching, the optical bench.

- The table/bench will need to be grounded.
- The laser light should be below or above eye level within sitting or standing.

- Vibration dampening is a consideration for laser optical tables.

When using equipment rack for lab equipment, the rack must also be:

- Seismically braced and grounded.
- Special note: equipment made to be rack mounted and used outside of the rack needs to be grounded as well.

Laser-Generated Air Contaminants (LGAC)/Fumes, Gas Cylinders, Toxic Gas Alarm

- Laser facilities using toxic gases or burning/cutting must have the appropriate ventilation (such as toxic gas cabinets). If hazardous chemicals will be used a chemical fume hood must be available.
- If laser uses toxic gas (e.g., excimer laser), toxic gas alarm system must be installed.
- Gas cylinder storage (restraints) if required shall be installed.

For excimer lasers:

- Ventilation system capable of maintaining an average face velocity of 200 fpm at the cabinet's window opening when the window is fully opened.
- Alarming airflow meter should be used to monitor and indicate low-flow conditions

2. Magnet Laboratories/Magnetic Resonance Imaging (MRI) facilities: NMR, MRI, EPR and other Strong Magnet Use Labs

If the facility will require the use of equipment that may generate large magnetic fields such as MRI/NMR/EPR, consideration must be given to assess the necessary magnetic field shielding requirements in the walls, ceilings, and doors. The EH&S Radiation Safety shall be consulted during the design and review process.

There are numerous and detailed considerations to be accounted for in the design of MRI's that need to be discussed and taken into consideration with the end user, MRI vendor, experienced shielding vendor, EH&S, and the design team.

The above should take into account the location and strength of the magnetic fringe fields with respect to exposure to general public, individuals with pacemakers, and other regulatory requirements.

Magnetic fringe fields and hazard warning signs

- Areas such as hallways, stairways, and offices shall be located where fields are <5 G to allow completely unrestricted access.
- Secure and restrict access to places where whole-body fields exceed 5 G. This is based on the possible effect that 5 gauss fields can have on some pacemakers. A variety of prosthetic devices, medical equipment, makeup, and personal articles can also behave in a hazardous manner in stronger fields.

- A visible indicator demarcating the 5 gauss line or floor postings of fringe fields should be installed after magnet start up. The indicator can be a temporary barrier or permanent floor marking.
- ANSI Z535 specification warning signs shall be posted at all entrances to superconducting magnet room, conspicuously warning of magnetic fields and associated hazards to prevent entry by unauthorized personnel.
- Signs should be mounted so as to be visible both at the doorway and at some distance from the doorway. Signs should not be mounted above doorways.
- A receptacle inside of the lab door for lab occupants to place credit cards, watches, cell phones, etc. may need to be considered depending on the strength of the magnet.

Cryogenic

Cryogenically cooled magnets using Liquid Nitrogen and possibly Liquid Helium must have oxygen sensors tied to the Toxic Gas Monitoring System (TGMS) and may require ventilation for magnet quench. Considerations must be given to storage space for liquid nitrogen/helium Dewar's as needed.

- In case of emergency, the discharge (deliberate or accidental) shall be made to direct cryogenic gases from a quenched superconducting magnet (loss of magnetic field) to a safe, unoccupied location to avoid exposing persons to an oxygen-deficient atmosphere. The gases generated by the rapid boil-off of liquid helium and nitrogen should be vented outside.
- Doors to locations that may be subjected to gases during a quench shall open outwards to assure they can be opened should the laboratory become pressurized.

The issue of preventing oxygen deficiency during a quench condition or discharge shall be addressed in the design of locations for superconducting magnets.

Room size

- For superconducting magnets which utilize liquid cooling, the magnet room must be large and high enough (the space between the ceiling and the level of seven feet in the room) to accommodate the initial volume of helium gas released from a quench. There must be adequate exhaust ventilation in the room of at least 10 air changes per hour.
- During a quench, one half of the helium volume will boil off and be violently ejected from the helium vent on top of the magnet within one minute. This vapor cloud will seek the highest point in the room as it warms and expands up to 700 times in volume.
- Oxygen sensors with associated local alarms must be installed in magnet rooms where there exists the potential for asphyxiation. Alarms for oxygen monitors installed in the magnet rooms must activate when levels of oxygen are below 19.5%.
- For superconducting magnet units that utilize larger volumes of cryogens or for magnets in smaller rooms or in rooms with inadequate ventilation, helium vent pipes hard-ducted

to the helium quench valve or automated exhaust fans tied to oxygen monitors must be installed.

3. Radio Frequency and Microwave Devices

Systems that emit radiofrequency (RF) energy as an intentional emitter need to be reviewed by EH&S if system power is in excess of 5W Effective Isotropic Rated Power (EIRP) to ensure that exposure levels meet the requirements of the WAC 296-32-22574 and those of the IEEE C95.1.

Unintentional emitters shall be shielded to preclude exposures in excess of the limits in the regulations and standards as noted above. All systems shall be designed to operate in a noninterference mode in accordance with 47 CFR 15 which may require the use of RF shielding.

General access controlled and hazard warning sign.

- Access to areas with RF and microwave devices should be restricted.
- Areas or locations where field strengths could exceed the MPE Level are required to have a hazard communication posting and/or barriers.
- The hazard warning sign should be mounted so as to be visible both at the doorway and at some distance from the doorway to identify such hazard areas. Signs should not be mounted above doorways.
- To prevent exposures exceeding the MPE for radio frequency electrical currents, barriers and/or cages shall be provided to protect persons from contact with or close proximity to such currents. These provisions shall be designed or reviewed by an Electronic Engineer experienced in radio frequency/microwave design.

For cell tower and equipment on rooftop

- All cell tower and equipment will be installed on rooftops with fall protection in place.
- Entrances to the rooftop locations will have UW guidelines and Information signs.
- Elevations and locations of signage and barriers shall be reflected on current as-built drawings.
- Location of signs on doors/walls shall be a minimum of 60 inches from the floor, unless otherwise specified.
- Hazard warning signs should be mounted so that they are visible from the walking working surfaces in locations to alert and inform the viewer in sufficient time to take appropriate evasive actions to avoid the potential harm from the hazards identified.
- Barriers located on the roof surface shall be ballasted. Installations of barriers requiring roof penetrations are prohibited.

4. Ultraviolet (UV) Radiation

This section provides general design and engineering guidance for the development and installation of safety controls in facilities containing UV light systems.

All UV light installation, shielding design, and area of use must be reviewed by EH&S prior to construction.

Please work with EH&S Radiation Safety to ensure all controls and safety measures are in place to protect people from exposures at or above the Maximum Permissible Exposure Levels (MPE) defined for Actinic UV Radiation Effective Irradiances.

General access controls and hazard warning sign:

- Engineering controls such as automatic shut off switches and locked doors provide superior protection over measures such as signage. Time limits for exposure are based on a person not using proper PPE.
- Access to areas or rooms with UV light should be restricted.
- Areas or locations where irradiance could exceed the MPE Level are required to have a hazard communication posting, illuminated warning light, and/or shielding.
- The hazard warning sign should be mounted so as to be visible both at the doorway and at some distance from the doorway to identify such hazard areas. Signs should not be mounted above doorways.
- Signs shall be placed on the UV source if the source is portable or moveable.

Windows/Viewing Area/Shielding

- All glass, windows, or visible access to the area should be covered with UV rated material for the wavelength of the UV source. These materials should be evaluated by the EH&S Radiation Safety prior to installation.
- All overhead or upper room UV uses for germicidal purposes should be reviewed by the EH&S prior to construction.
- UV used for sterilization of water or other materials or solutions should be properly shielded. Devices of this type can put out significant amounts of UV above the MPEs.

5. References

1. ACGIH – TLV/BEI 2017
2. IEEE C95.1-2019 - Standard for Safety Levels with Respect to Human Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz
3. ANSI Z136.1-2014 - Safe Use of Lasers
4. NFPA 115 – Standard for Laser Fire Protection
5. ICNIRP “Guidelines on Limits of Exposure to Static Magnetic Fields” 2009.

6. ICNIRP "Guidelines for limiting exposure to electromagnetic fields (100 kHz to 300 GHz)" 2020.
7. The American College of Radiology Guidance for Safe MR Practices