G_005 - Safety training for Guest Workers* at LLE

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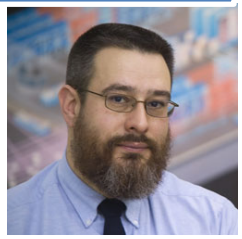
Chief Safety Officer

Milt Shoup Mechanical Safety	Eugene Kowaluk Laser Safety	Ken Marshall Chemical Safety	John Sawyer Fire Safety	Walter Shmayda Radiation Safety	John Reid Electrical Safety
					

* This training is not intended for contractors (plumbers, electricians, mechanics, etc.)

Summary

- LLE's Safety Officers are available to discuss any questions or concerns you have about safety policies and practices at LLE
- Most Guest Workers can complete this one training module to satisfy all LLE safety training requirements
  - Workers needing access to LaCave or the OMEGA Target Bay must also complete C_002 – Beryllium Safety Training
- This presentation does not cover radiation safety training. Interested persons must contact the Radiation Safety Officer for guidance.
- Workers who engage in laboratory activities at the Laboratory for Laser Energetics (LLE) need to understand and follow site-specific safety policies
- All workers must read and follow instructions on signs when entering a laboratory space
- The Laser Facility Manager and Safety Officers must authorize operation of any equipment (e.g., laser, machine) having compromised Engineering Controls (interlocks, safety enclosures, etc.)

This training is for Guest Workers who need to work in laboratory areas

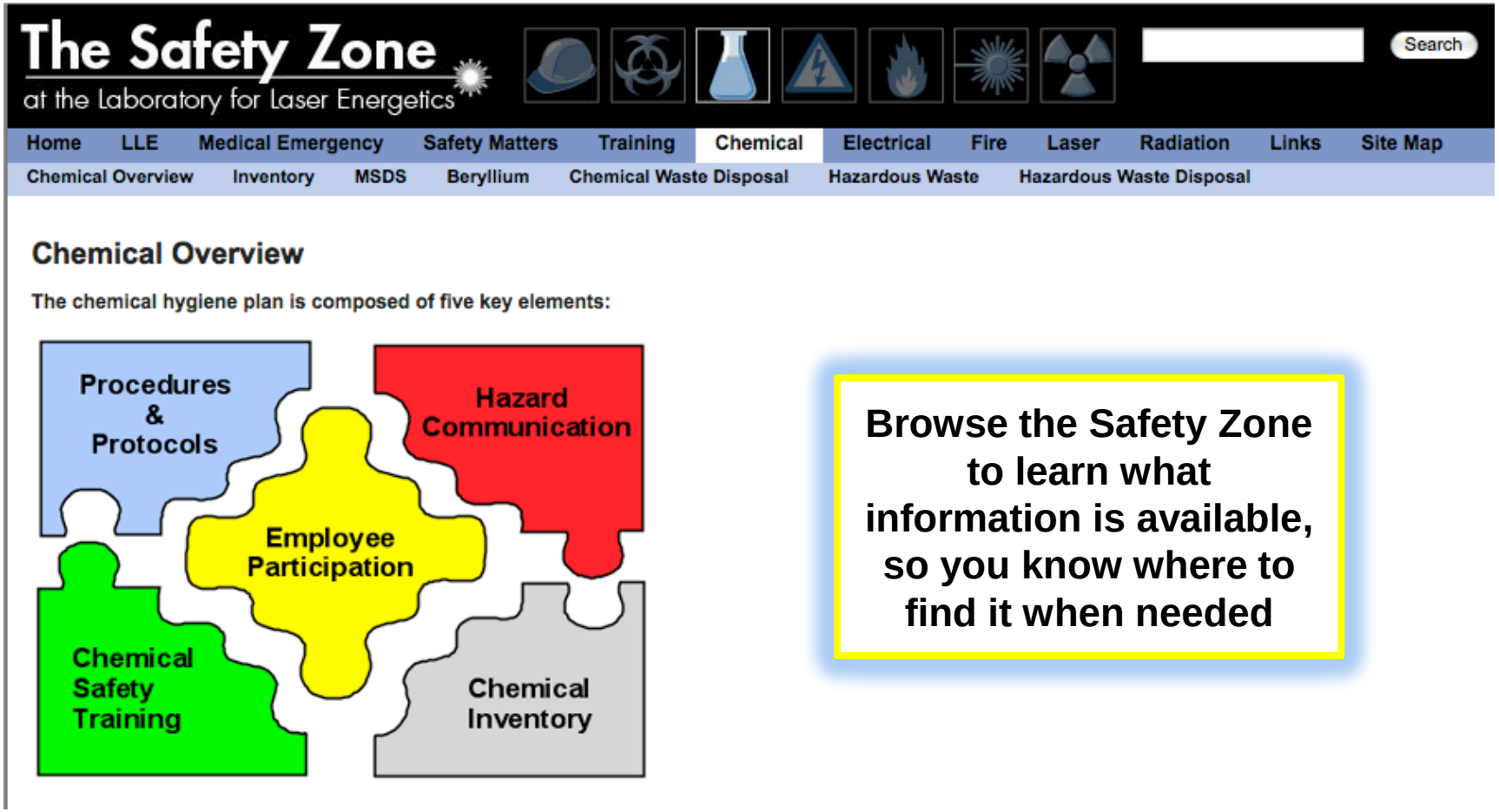
- **Principal Investigators, scientists and others do *not* need to complete this training *unless* they need laboratory access.**
- **Persons who must complete this training include:**
  - **Instrument Specialists**
  - **Instrument Technicians**
  - **Persons needing access to:**
    - **OMEGA Target and Laser Bays, LaCave, Darkrooms**
    - **OMEGA EP Target/Laser Bay, Diagnostic Bays**
    - **Target Fabrication labs**
    - **EP Diagnostic workshop (Rm. 6106), D-TIM lab (Rm. 175), Diagnostic setup labs (Rms. 177 & 182)**

Outline

- **Overview**
- **LLE General Laboratory Safety Policies**
- **Personal Protection Equipment (PPE)**
- **Laser Safety**
- **Mechanical Safety**
- **Compressed Gas Safety**
- **Electrical Safety**
- **Chemical Safety**

LLE safety information is available at the “Safety Zone”

http://safety.lle.rochester.edu/



Browse the Safety Zone to learn what information is available, so you know where to find it when needed

LLE's expectations of Guest Workers

- **Immediately report any injury, "near-miss" or unsafe condition to your LLE supervisor, Shot Director or an LLE Safety Officer**
- **Workers who engage in laboratory activities at LLE need to understand and follow site-specific safety policies**
- **LLE maintains extensive procedures describing operation of experimental equipment. Guest Workers are:**
  - **Responsible for obtaining procedures for equipment they wish to operate and understanding them before beginning work.**
  - **Asked to provide feedback to help improve procedures.**

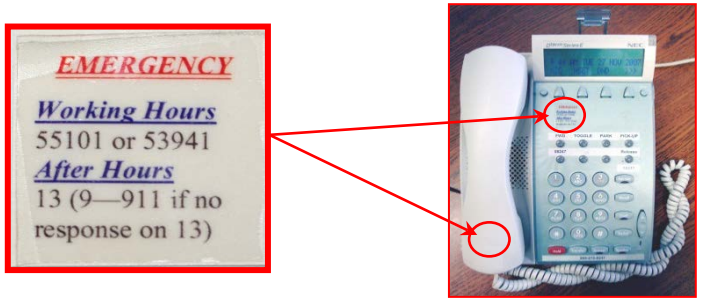
Guest workers must be trained and authorized by their host institution to perform all tasks that they will conduct at LLE

Outline

- Overview
- ➢ LLE General laboratory safety policies
- Personal Protection Equipment (PPE)
- Laser Safety
- Mechanical Safety
- Compressed Gas Safety
- Electrical Safety
- Chemical Safety

Know what to do and who to call when something goes wrong

Injuries / emergencies / major spills



Know where eye wash stations and safety showers are located and how to use them

Guest Workers may NOT perform these activities without additional training

- **Service energized equipment, unless following written, LLE-approved procedures**
- **Remove "Danger - Do Not Operate" tags**
- **Use ladders > 6 feet (1.8 m) tall, rolling stairs, aerial lifts, or perform activities requiring fall protection**
- **Operate hoists or cranes, or perform rigging operations**
- **Use cryogens (e.g. liquid N_2)**
- **Chemical processes**
- **Modify, or authorize changes to equipment, software, or procedures**
- **Allow people to enter LLE buildings**
- **Activities requiring a respirator**
- **"Hot work" (e.g. open flames, welding)**
- **Fight fires**
- **Machine shop work**

Definitions

OMEGA

- **Includes any part of the OMEGA or OMEGA EP experimental facilities and support laboratories**

Supervisor

- **While supporting an experimental campaign on OMEGA or OMEGA EP, the on-watch Shot Director (SD) from that facility is your supervisor.**
- **The SD must**
  - **Sign Work Authorization Permits (WAP) before Guest Worker laboratory activities may begin**
  - **Ensure that guest worker's safety training is current**
- **The SD may delegate support and supervision of guest workers to one or more LLE employees**

Definitions (continued)

Laboratory areas include (but are not limited to):

- **OMEGA Target and Laser Bays, LaCave, Darkrooms**
- **EP Target/Laser Bay, Diagnostic Bays, Darkrooms**
- **Target Fabrication labs**
- **Diagnostic workshop (Rm. 6106), D-TIM lab (Rm. 175), Diagnostic setup labs (Rms. 177 & 182)**

The Occupational Safety and Health Act of 1970

Each employer (including LLE) shall furnish … a place of employment which is free from recognized hazards that are … likely to cause death or serious physical harm to his employees;

Each employee (including guest workers) shall comply with … all rules… applicable to his own actions and conduct.

Inform LLE management of safety hazards.
Be responsible for your conduct.

“Stop work” policy

Everyone has the right *and RESPONSIBILITY* to “Stop work” if they perceive an *Imminent Danger*

- **An imminent danger is a hazard that presents an unacceptable risk of injury, environmental impairment or property damage.**
- **No one should undertake a job that appears unsafe**
- **Hazards may result from**
  - **defective equipment,**
  - **failure to follow procedures,**
  - **equipment or techniques that are unsuitable for a task,**
  - **or unforeseen circumstances.**
- **Immediately notify LLE management:**
  - **Shot Director, Laser Facility Manager, and/or Safety Officers**

“Buddy System” policy

Guest workers are required to use the Buddy System when working in laboratory spaces at LLE

- **Buddies are responsible for**
  - **Being available to assist in an emergency**
  - **Verifying proper PPE and safe work practices are used**
  - **Remaining in contact with partner, and knowing he/she is OK**

Equipment must be qualified before operating it at LLE

- **No equipment may be operated at LLE unless it has been approved by LLE management, as described in LLE Instruction 7700**
- **Guest workers must be granted explicit authorization prior to operating any equipment at LLE**
- **All equipment brought to LLE by guest workers will be installed on the OMEGA facility by LLE staff. Guest workers may supervise and assist if authorized by the WAP.**

Cables, fibers, hoses, etc. that are to become permanent, or those longer than ~12 feet, are to be installed by LLE staff

This is necessary to ensure that cables:

- **Meet electrical safety standards,**
- **Follow designated paths,**
- **Remain clear of beam paths,**
- **Do not interfere with moving mechanical equipment,**
- **Are properly strain relieved, and**
- **Do not overload cable trays.**

LLE seeks to minimize safety risks

- **Operational risks are mitigated to the maximum extent practical by:**
  - **Engineering controls (interlocks, guards, pressure relief valve, …)**
  - **Procedures and training**
  - **Administrative controls (restricting access, buddy system, …)**
  - **Personal protective equipment (PPE)**
- **Never alter, remove or defeat safety features; examples include software and hardware interlocks, guards on moving machinery, electrical and laser enclosures**
- **Keep procedures accurate**
  - **Read and understand procedures before starting work**
  - **Stop and obtain clarification for procedures that are unclear or inaccurate**
  - **The Laser Facility Manager (LFM) must authorize deviations from procedures**

Good housekeeping is essential to maintaining a safe work environment

- **Promptly correct slippery conditions on walkways and work surfaces**
- **Keep aisles and passageways unobstructed.**
- **Set up barriers when passage is encumbered by work-in-progress or activities prevent safe passage**
- **Promptly remove all clutter, tools, hardware, packaging and similar material**
- **Maintain a 3 foot (1 m) clear area around circuit breaker panels**
- **Eliminate trip hazards. Secure hoses, cables and other potential trip hazards overhead, under walkways, or cover them with a cable ramp**

Everyone must help maintain a clean and organized work environment

Fire Safety

- **Do**
  - **Maintain 18 inch (0.5 m) clearance below fire sprinkler heads**
  - **Minimize storage of flammable materials (paper, packing materials, chemicals, …)**
- **Do not**
  - **Prop open or prevent fire doors from closing**
  - **Obstruct hallways, stairways, doors or exits**
  - **Block fire extinguishing equipment or fire alarm pull stations**
  - **Place or store items on electrical raceways**
  - **Attach items to, or drape items over, fire suppression system (e.g. pipes & sprinklers)**
  - **Bring personal appliances to LLE (heaters, toasters, coffee makers, refrigerators, microwave ovens, halogen lamps, etc.)**
  - **Park within 15 feet of a fire hydrant**

Respond immediately to fire alarms

- **All personnel must**
  - **Close windows and doors while exiting, if possible**
  - **Exit through the nearest safe stairway/door**
  - **Evacuate and move 50 feet (15m) away from the exit**
  - **Stay clear of emergency responder access, and**
  - **Remain clear until alarms are silenced and beacons are off.**

In an emergency, Guest Workers must report to their LLE supervisor after exiting the building

Do not share personal items assigned to you by LLE

- **ID cards**
- **Computer accounts & passwords**
- **Radiation badges**
- **Keys**
- **Confidential personal information**

Each individual is personally responsible for the appropriate use of items assigned to them

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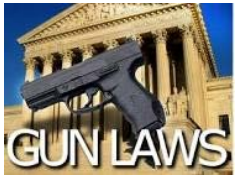
Redundant safety barriers reduce the risk of accidents and injury

- **Engineering controls (interlocks, guards, pressure relief valve, …)**
- **Procedures and training**
- **Administrative controls (restricting access, buddy system, …)**
- ➢ **Personal protective equipment (PPE)**

Accident waiting to happen

Redundant safety barriers

Policies



Training

Engineering controls

Should you rely on PPE?

PPE *NEVER* prevents an accident, but it *may* reduce the severity of injuries. Prevent accidents!

PPE is your LAST form of protection

- **PPE is effective, only when properly maintained and used**
- **Many types of PPE are designed to withstand a single catastrophic event (e.g. hard hats, impact-resistant safety glasses).**
  - **If such an event occurs, or if the PPE appears to be damaged, remove it from service immediately!**
- **Some PPE is designed for single-use to prevent spread of contamination (e.g. chemical gloves, lab coats, ear plugs).**
  - **Discard single-use PPE after use.**
- **Know the capabilities and limitations of the PPE you use, and use it accordingly**

Wear your PPE when required!

PPE is provided by LLE*

- **Some areas within LLE require workers to wear PPE. Most rooms have signs indicating the type of required PPE**
- **Types of PPE include**
  - **Laser glasses**
  - **Impact-resistant safety glasses**
  - **Hardhats**
  - **Lab coats, shoe covers, hair nets/covers**
  - **Safety shoes (required when moving items ≥ 50 lbs. (22 kg))**
  - **Face shields (must be used with safety glasses)**
  - **Gloves**
  - **Hearing protection**

*** LLE can provide only non-prescription safety eyewear for guest workers, and may not be able to provide safety shoes. LLE personnel will move and rig items > 50 lbs.**

Maintenance (cleaning) and care of PPE is the responsibility of the user

- **Keep PPE clean and in good working order**
- **Check the PPE before each use**
- **Wear the PPE correctly**
- **Immediately remove damaged PPE from service; return it to the work area supervisor who will dispose of it and replace it**
- **Do NOT move PPE from one laboratory to another.**
  - **For example: do not “upgrade” your laser safety glasses from another lab, the wavelengths may not be compatible**

Not all safety equipment is interchangeable!
Laser safety glasses ≠ Mechanical safety glasses ≠ Chemical safety goggles

Dress properly when working in laboratory areas

- **Understand what PPE is required, wear it as prescribed**
- **No open-toed shoes (e.g. sandals)**

- **Wear long pants, without cuffs**
- **Wear cleanroom or protective garments to keep street clothes clean and to prevent street clothes from contaminating the lab.**

Is your buddy properly dressed, and using PPE correctly?

Safety glasses of the appropriate type must be worn under the following conditions

- At all times in the following areas:
  - OMEGA Facility areas (Laser Bays, Target Bays, LaCave)
  - Any room where Class 3B or Class 4 lasers with free-space beam propagation are in operation
  - All LLE Mechanical rooms
- By all persons working or passing within 20 feet (6 m) of:
  - Chemical processes, including film developing, optics cleaning, etc.
  - Compressed gas system operation
  - Vacuum system operation
  - Activities that have the potential to generate particulate, debris, or projectiles
- All other laboratory areas are managed at the discretion of the LLE supervisor, based on the above criteria.

All safety glasses and goggles used at LLE (Mechanical, Laser, Chemical) must satisfy ANSI Z87.1 impact resistance standards

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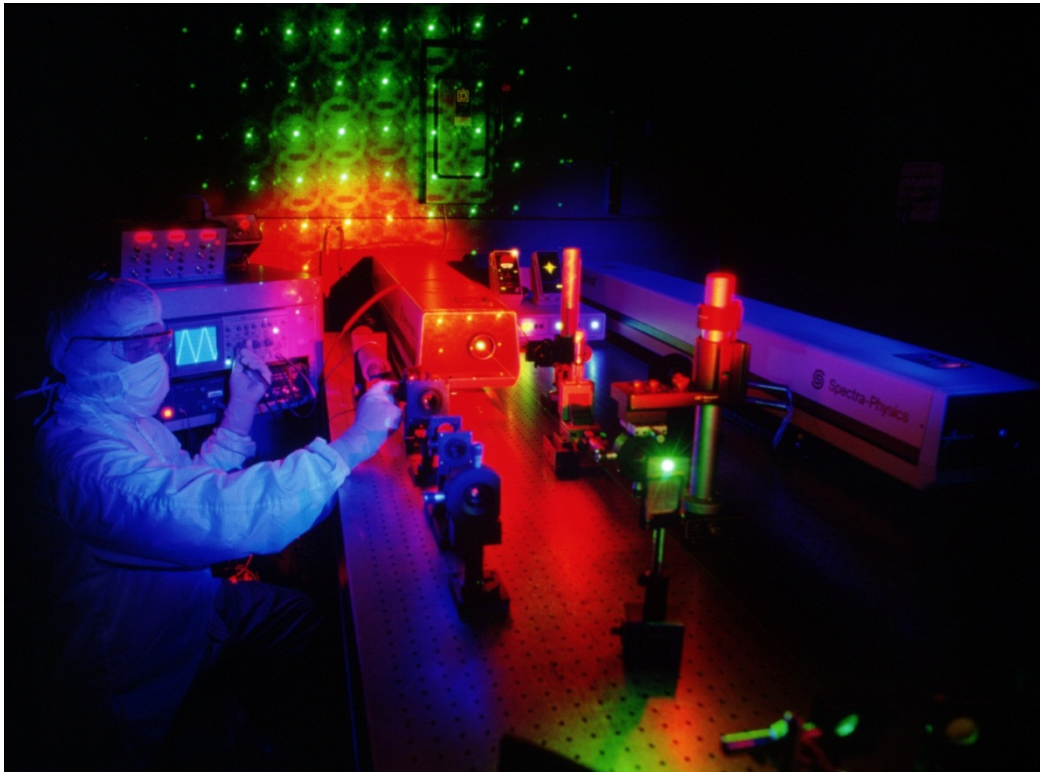


Persons completing this training have limited authority to operate lasers at LLE

Allowed:

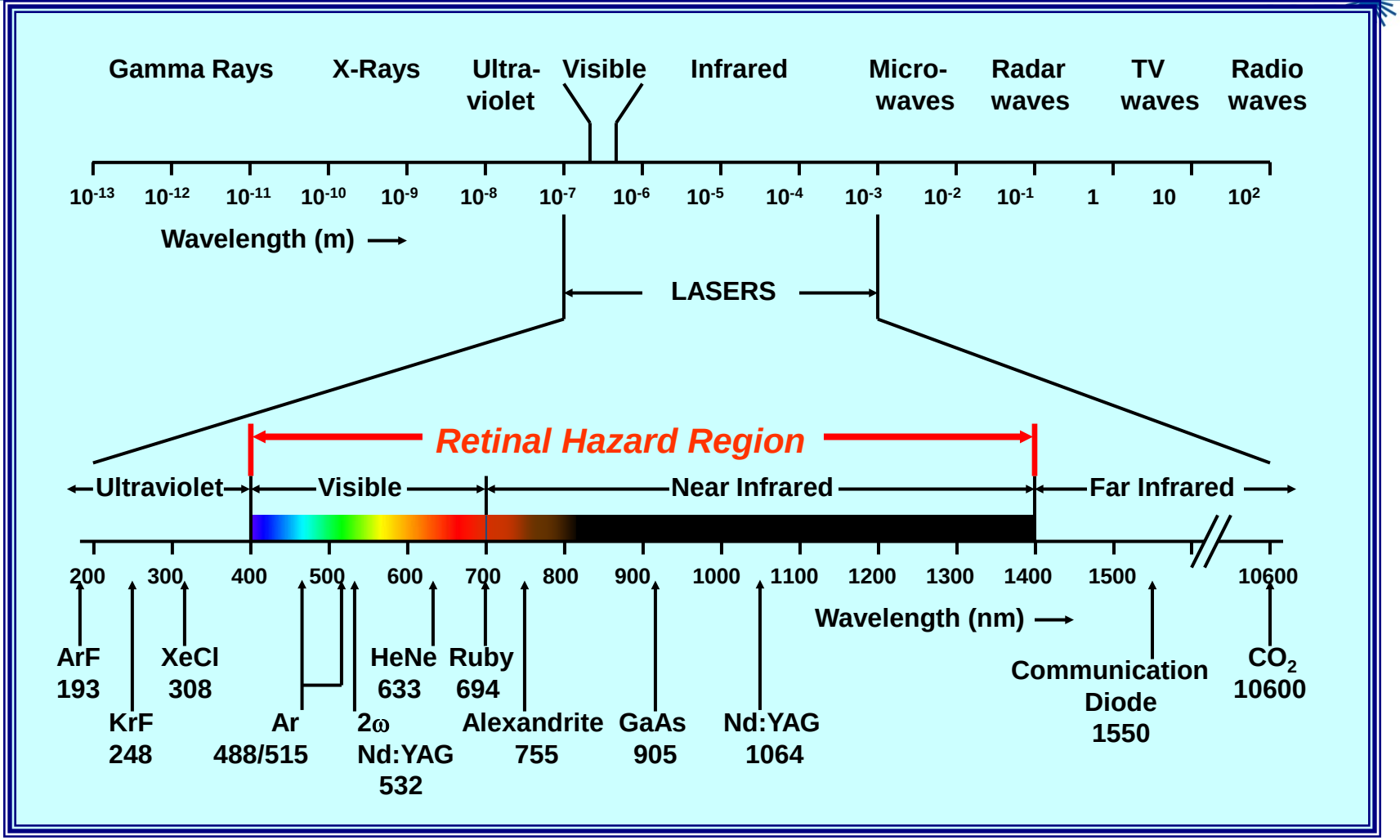
- **Work in an environment where lasers are being used**
- **Setup and operation of lasers up to and including Class 3B, subject to limitations above and**
  - **LLE approved, written procedures must be followed for all operations using Class 3B (and Class 4) lasers**

Prohibited:

- **Modification of any LLE approved laser system**
- **Operation of any laser that is not fully assembled with all engineering controls operational**
- **Making repairs**
- **Setup and/or operation of Class 4 lasers**

Persons working at LLE under these restrictions are not required to participate in medical surveillance (i.e. no eye examination is required)

Laser spectrum



*Courtesy, laser-professionals.com

The most common causes of laser-related ***ACCIDENTS*** are easily mitigated

Cause	Mitigation
Misaligned optics and upwardly directed beams	Align with low power, terminate all beam paths
Unanticipated eye exposure during alignment	See above
Equipment malfunction	Perform regular maintenance. Provide additional controls before bypassing safety features
Improper methods of handling high voltage	Operator training, written procedures, de-energize when servicing
Unintentional exposure of unprotected personnel	Controlled access
Operators unfamiliar with laser equipment	Qualify all operators
Lack of protection for ancillary hazards	Failure mode analysis. Understand potential hazards and mitigate by design
Improper restoration of equipment following service	Repairs performed by trained, qualified personnel
Failure to follow operating procedures	Read, understand & follow procedures

THE PRIMARY CAUSE OF LASER EYE *INJURIES* IS UNSAFE WORK PRACTICES *COMBINED* WITH THE *FAILURE TO USE PROTECTIVE EYEWEAR* PROPERLY!

Laser radiation can cause *irreversible* damage to the eyes and skin

- **The eye can intensify (focus) light 100,000 times making eye exposure the principal hazard associated with laser radiation.**
- **Ultraviolet radiation (180-400 nm) causes damage to the cornea.**
  - **Excessive ultraviolet exposure produces photophobia, an intolerance to light.**
  - **Adverse effects are usually delayed for several hours after the exposure but will occur within 24 hours.**
  - **Cumulative exposure can contribute to cataracts (clouding of the lens).**
- **Visible and infrared radiation (400-1400 nm) can damage the retina.**
- **The principal cause of tissue damage is thermal in nature**
  - **Thermal effects are caused by absorption of laser energy**

Maximum Permission Exposure (MPE) is the maximum level of laser radiation that does not cause adverse biological changes in the eye or skin

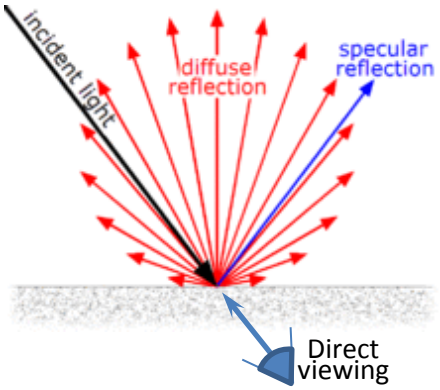
Lasers are classified according to their hazards

- **Class 1** incapable of producing damaging radiation levels during operation and maintenance

- **Class 1M** incapable of producing hazardous exposure conditions during normal operation unless the beam is viewed with an optical instrument such as an eye-loupe (diverging beam) or a telescope (collimated beam)
- **Class 2** emit in the visible part of the spectrum, and eye protection is normally afforded by the aversion (blink) response which is typically less than 0.25 s. Their emission limit is 1 mW.

- **Class 2M** emit in the visible portion of the spectrum, and eye protection is normally afforded by the aversion response for unaided viewing, however, Class 2M is potentially hazardous if viewed with certain optical aids.

Class 3 lasers may be hazardous when viewed directly or by specular reflection, but they are not normally a diffuse-reflection or fire hazard



Class 3 lasers have two subclasses:

Class 3R **(formerly Class IIIa) low-power and potentially hazardous under some direct and specular reflection viewing condition if the eye is appropriately focused and stable, but the probability of an injury is small. Their continuous wave (CW) emission limit is 5 mW.**

Class 3B **medium-power lasers and may be hazardous under direct and specular viewing conditions. Their CW emission limit is 500 mW.**

Class 4 lasers have the greatest potential to cause injury

Class 4 lasers

- **Are a hazard to the eye and skin from the direct beam,**
- **May pose a diffuse reflection or fire hazard, and**
- **May also produce laser generated air contaminants and hazardous plasma radiation**
- **May not be operated by Guest Workers**

Class 3B and Class 4 lasers require a safety review, engineering and administrative controls, operating procedures, and PPE prior to use

Many collateral hazards are associated with lasers

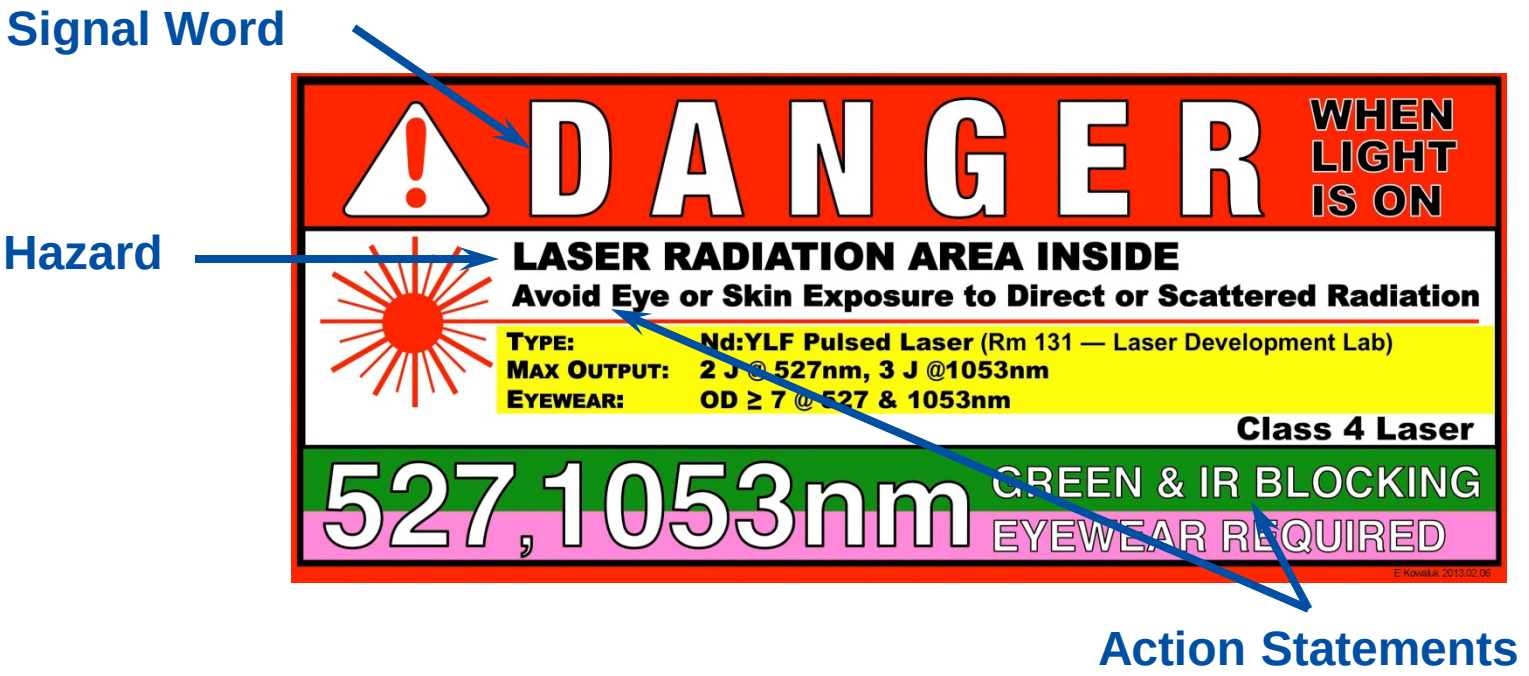
- **Radiation: can be produced by power supplies, capacitors, or discharge lamps that produce x rays, UV, visible, IR, and microwave radiation**
- **Electrical shock: can occur during laser set-up or installation, maintenance, and service, where protective covers are often removed to allow access.**
- **Other hazards include:**
  - **Excessive noise from high-power lasers,**
  - **Explosive failure of high power flash-lamp cables & connectors,**
  - **Fire.**

Warning signs address different environments

The laser safety standard, ANSI Z136.1 along with the Center for Devices and Radiological Health, use the following signal words:

- **DANGER — Indicates an immediately hazardous situation which, if not avoided, will result in death or serious injury. Only Class 3B & Class 4 lasers require this signal word.**
- **CAUTION — Indicates a potentially hazardous situation which, if not avoided, may result in minor or moderate injury. "CAUTION" may also be used to alert against unsafe practices. The signal word "CAUTION" shall be used with Class 2, 2M, 3A and 3R that do not exceed the applicable MPE.**
- ***NOTICE* — Indicates company policy as the message relates directly or indirectly to the safety of personnel or protection of property.**

Warning signs address different hazards and use specific wording

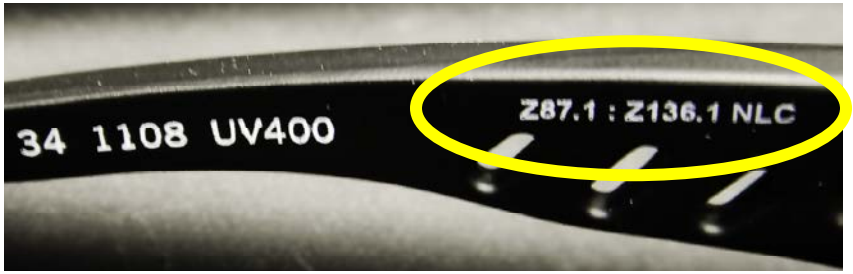


- False color is added to indicate the wavelength
  - Pink for infrared, violet for ultraviolet, etc.
- The signal word, DANGER, alerts visitors to the possibility of injury
- The alert is only in effect when the light is flashing

LLE requires laser-safety eyewear to comply with two ANSI standards, Z136.1 and Z87.1

This image shows applicable ANSI (American National Standards Institute) standards printed on the glasses temple:

- **Laser safety, Z136.1, and**
- **Mechanical impact resistance, Z87.1**



Transmission characteristics are labeled in accordance with ANSI standard Z136.1 on the left side of the image above, as are LLE signs

Understand the meaning of, and how to read laser glasses protection information

Optical Density (OD) is the logarithmic ratio of the radiation incident upon a material and the radiation transmitted through it.

$$OD = \log_{10}\left(\frac{I_{incident}}{I_{transmitted}}\right)$$

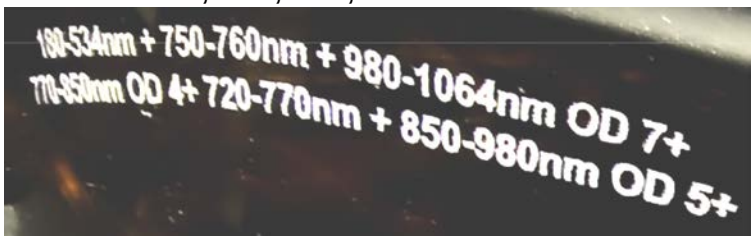
- A higher OD value means the laser glasses provide greater protection.
- The OD of a material depends on the wavelength (color) of the incident light.

Examples

- OD 1 lenses reduce transmitted light intensity by a factor of $10^1 = 10$
- OD 9 lenses reduce transmitted light intensity by a factor of $10^9 = 1{,}000{,}000{,}000$

Label text

- 180-534nm + 750-760nm + 980-1064nm OD 7+
- 770-850nm OD 4+ 720-770nm + 850-980nm OD 5+



Interpretation

- For the wavelength ranges (180-534nm) AND (750-760nm) AND (980-1064nm) EXCEEDS OD 7
- For the wavelength ranges (770-850nm) EXCEEDS OD 4
- For the wavelength ranges(720-770nm) AND (850-980nm) EXCEEDS OD 5

Read laser glasses ratings and carefully compare them to door signs. Glasses may look similar, but afford different levels of protection.

Guidelines for working in a laser environment

Before entering

- **Verify laser safety eyewear is rated for the optical density and wavelength(s) indicated on the warning sign**
- **Put on laser safety eyewear and other required PPE**
- **Look in a mirror (if available) to verify you are wearing all required PPE and, when required, cleanroom apparel**

While working

- **Request supplemental lighting if needed to compensate for visible light attenuation of the laser glasses**
- **Wear your safety eyewear close to your eyes**
- **Turn toward the object you want to see (do not look around your glasses)**
- **Use the minimum laser power for the required task**
- **Terminate all beam paths**

Optical Fiber Transmission Systems

- **Optical cables (fibers) are considered enclosed systems with the optical cable forming part of the laser enclosure.**
- **If the fluence in a fiber is below the MPE, fiber connectors may be disconnected in an area with no control measures.**
- **Fibers attached to a Class 3B or Class 4 laser sources shall not be disconnected prior to disabling the source.**
- **If emission could exceed the MPE, then the following applies (ANSI 4.5.2):**
  - **Connectors shall be labeled “Hazardous Laser Radiation when Disconnected.”**
  - **The laser source shall be capable of lockout/tagout**

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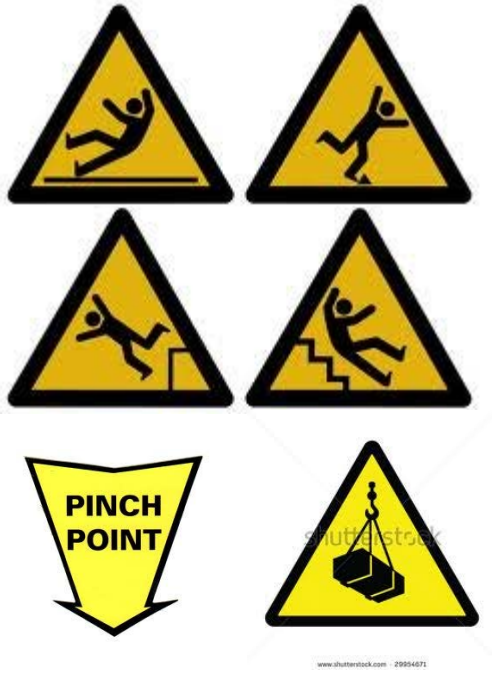
LLE's Mechanical Engineering department has many responsibilities

- **Ensure the safety of mechanical equipment and its use**
- **Inspect gas and vacuum systems prior to operation**
- **Prepare and review safety analyses of mechanical hardware**
- **Review all proposed changes to mechanical equipment, including joints (fasteners, bolt torque specifications, hardware changes, …)**
- **Perform interference analysis for equipment, specialized target designs, experimental configurations**
- **Review and approve materials used in vacuum, optical assemblies and cleanrooms**

Numerous mechanical hazards exist at LLE

- Tripping
- Falling objects
- Cutting/abrasion
- Pinch points
- Elevated work surfaces
- Bump hazards
- Noise
- Slipping …



Situational Awareness – The best way to prevent an accident is to be aware of your surroundings

Stored energy is a common metric for evaluating the potential risk associated with equipment and systems

Common mechanical energy storage mechanisms include:

- **Gravity acting on any elevated mass**
- **Springs**
- **Compressed gases**
- **Vacuum vessels**
- **Pressure vessels**
- **Motors/actuators (any rotating machinery)**
- **Thermal sources**
  - **Heat**
  - **Cryogens**

The uncontrolled release of stored energy can cause personal injury and collateral damage to nearby equipment

Safely-designed equipment can be made unsafe by altering its construction or operating conditions

- **Guest workers must use LLE approved drawings and follow LLE assembly procedures when building equipment for use at LLE**

- **ME must provide explicit authorization for:**
  - **Deviations from assembly procedure**
  - **Material substitutions**
  - **Changes to joint design, including fastener changes (material, grade, size, etc.)**
  - **Changes to fastener torque specifications**

Manual lifting at LLE

- **The National Institute for Occupational Safety and Health (NIOSH) provides the guidelines for the manual movement of materials**
  - **The NIOSH maximum suggested lifting weight limit is 51 lbs. (23 kg) under ideal conditions**
- **Recognize your own physical limitations**
- **Guest workers may not operate rigging equipment at LLE. Request assistance from your supervisor**

Use common sense when manually moving material. If it feels heavy or is marginally controllable, stop and get help

Secure overhead components to prevent them from falling

- **Store small/loose items in bins or containers**
- **Materials used >4 feet (1.2m) off the ground must be secured to prevent them from becoming a falling object (An elevated deck surface is not the ground)**
- **Attachments must be capable of withstanding all likely loads with a general purpose safety factor of 3X**
- **Temporary attachments including tape and magnetic bases should not remain in use for more than 30 days**
  - **Tape must not be used for securing any mechanical loads**
  - **Magnets may not be used on near-vertical surfaces or overhead**

Hand tools and small power tools may be used without specialized training

- Use the proper tool for the job (i.e., the human hand is not a hammer)
- Use proper PPE (safety glasses, face shield, gloves, etc.)
- If you are uncertain how to use a tool, get assistance:
  - Read the manual and use the tool according to manufacturer's recommendations
  - Review the use with another qualified operator
  - Ask for help in the machine shop from a machinist

Follow manufacturers tool use and safety recommendations

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Compressed gasses present personnel hazards

- Stored potential energy
- Physiological hazards
  - Asphyxiation: the most common gas risk to personnel since nitrogen accounts for the majority of the gas used at LLE (others include helium, argon, CO_2, SF_6, …)
  - Flammability: these gases must be used in specially designed systems to mitigate fire safety risks (e.g. Hydrogen, methane, isobutane, acetylene)

  Oxidizer: can support and vigorously accelerate combustion in the presence of an ignition source and a fuel
  - Pyrophoric: gas with an autoignition temperature in air below 130°F (e.g. acetylene)
  - Toxicity or Reactivity: these gases must be used in fume hoods to maintain personnel safety
- Read and understand the Material Safety Data Sheets (MSDS) for each gas type used

Flammable gases pose additional risks

Flammable gases and gas mixtures must be used and stored in a well-ventilated area, that is readily accessible in case of emergency

Electrically ground flammable gas systems

Use spark-proof tools when changing regulators

LLE defines several gas system classifications

- **Low pressure: Systems that use “house” air or nitrogen and commercial air compressors designed for <150 psi (10 bar)**
- **High pressure: Includes all bottled gas sources (regardless of pressure) and equipment capable of developing >150 psi (10 bar)**
- **Flammable: gas systems are a subset of high pressure systems (all use bottled gas at LLE). Gas suppliers identify flammable gasses based on the gas species and in the case of gas mixtures, species concentration.**
- **Vacuum: systems with a volume greater than 0.4 m^3 must be analyzed, inspected and approved by ME prior to operation**

High pressure and Flammable gas systems must be operated according to LLE approved written operating procedures

Safety glasses must be worn by all persons within 20 feet (6m) of compressed gas or vacuum system operation

Compressed gas training requirements

- **High pressure systems (including flammable gas systems) must be set up*, inspected and leak-checked by persons who have completed Compressed Gas training (M_002)**

- **Low pressure and high pressure systems may be operated (not set up) by persons who have completed Mechanical Safety training (M_001) or Safety training for Guest Workers (G_005).**
  - **Operations must be performed according to written, LLE approved procedures**

- **Users of cryogenic liquids (e.g. N_2) must complete Compressed gas training (M_002) and possibly Liquid Nitrogen Fill Station training (C_003)**

* Setup includes installing the regulator, routing pressurized lines, making connections and performing leak checks

Gas system definitions

- **MOP – Maximum Operating Pressure**
  - **The maximum nominal operating pressure of a gas system**

- **MAWP – Maximum Allowed Working Pressure**
  - **The maximum pressure that a gas system can be charged to**
  - **Pressure Relief Valves (PRV) are set to this pressure**
  - **MAWP = 1.2 X MOP**
  - **MAWP is defined by the gas system component with the lowest pressure rating**

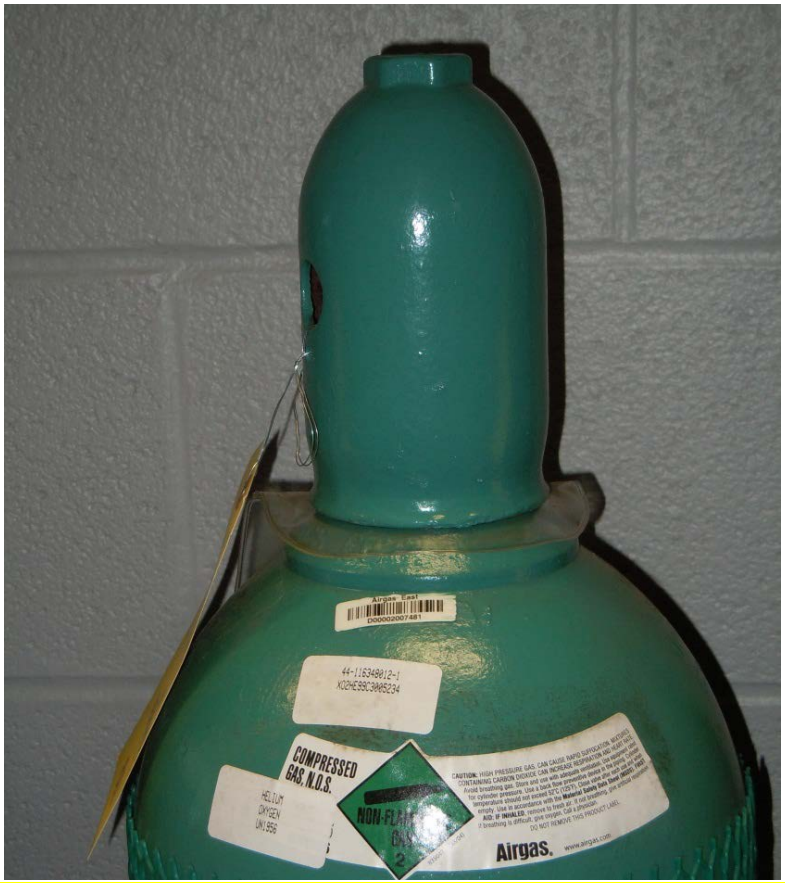
Never operate a gas system in excess of the Maximum Operating Pressure

Gas cylinder storage at LLE

- **Store cylinders in Shipping and Receiving when they are not in use**
- **Individually secure cylinders to a wall bracket, bench clamp, or transport cart**
- **Install a cylinder cap, except when in use**
- **Label and separate empty and full cylinders**
- **Store flammable gas cylinders in their designated location**

≥ 20 feet (6 m)

Large gas cylinders must be stored and transported with a cylinder cap installed



Cylinders lacking a legible label must not be used and must be returned to the supplier

Use tags to keep track of the cylinder fill status

Follow these steps when moving a gas cylinder

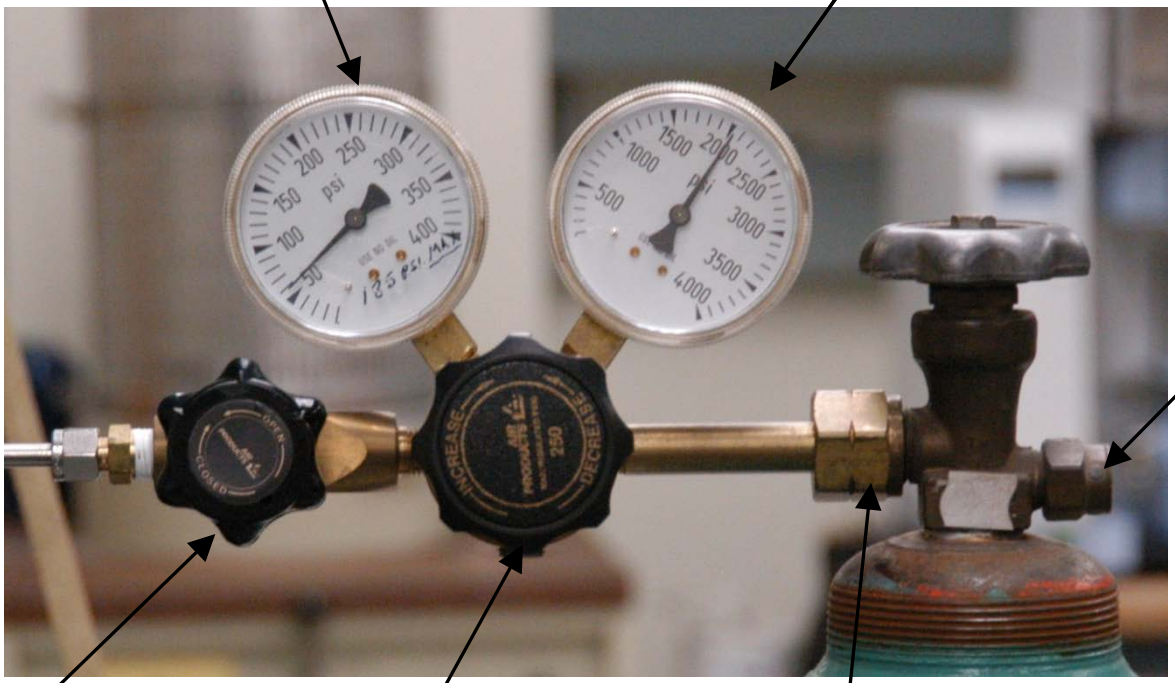
Before moving,

1. **Check the label for proper contents**
2. **Listen for leaks. If a cylinder is leaking, notify Shipping and Receiving staff immediately**
3. **Make sure the cylinder cap is on tight**
4. **NEVER lift a cylinder by the cap**
5. **Secure the upright cylinder to a cylinder cart or hand truck**
    1. **Small cylinders may be moved on a cart that has sides to prevent them from rolling off**

While moving,

1. **Avoid mechanical shock which could damage the valve, safety device or the cylinder**

Regulators may look alike, but are designed for use with specific gases and gas families



Never modify or attempt to repair any component of a regulator

All gas cylinders are equipped with a “frangible disk” Pressure Relief Device (PRD)

If you discover a cylinder with a leaking PRD,

- **Evacuate the area**
- **If it is a flammable gas, pull a fire alarm**
- **Notify a supervisor or safety officer. Provide information about the gas**
- **Do not return to the area until authorized by LLE Management**

Never attempt to tighten or repair a PRD

Only persons who have completed compressed gas training (M_002) may assemble a compressed gas system

- **Read and understand operating procedures for the equipment being prepared**
- **Obtain all required equipment (regulator, fittings, hoses, snoop, special tools, etc.)**
- **Transport the gas cylinder to the point of use on a cylinder cart**
- **Secure the cylinder to a stationary fixture**
- **Request assistance of a Compressed Gas worker (someone who has completed M_002) to assemble the system according to procedures, and to perform the leak check**

Every gas system must be checked at low pressure for leaks following assembly/installation

- **Pressurize the system to ~15 psig (1 bar), close the cylinder valve, and verify the pressure remains stable for at least 15 minutes.**
- **If a pressure drop is detected, leak test joints and fittings with SNOOP (stocked in the Shipping and Receiving area) or an electronic leak tester. Do not use soaps or other products that might leave organic residue or corrode regulator components.**
- **All leaks must be corrected before a pressurized gas system may be operated**

Operating a compressed gas system

- **Do not proceed until a compressed gas worker has verified system leak integrity**
- **Set the regulator output pressure to minimum by turning the regulator pressure control knob counter-clockwise**
- **Position yourself so the cylinder is between you and the regulator.**
- **Partially open the cylinder valve and listen for leaks, then fully open the valve if none are detected**
- **Adjust the working pressure by turning the pressure control knob, while observing the delivery pressure gauge**
- **Do not exceed the maximum pressure indicated on the regulator**
- **With gas flowing through the system, some adjustment may be required to the regulator**
- **Shut off the cylinder valve when the gas supply is no longer needed**

Additional rules pertaining to gas cylinders

- **Do:**
  - **Use small cylinders in lieu of lecture bottles. Lecture bottles are costly to dispose of (~$1,000) and should only be used as a last resort**

- **Do NOT**
  - **Transport a gas cylinder in your car**
  - **Permit cylinders to come in contact with electrical equipment**
  - **Allow hand lotion, oil, grease, or other organic substances to come in contact with cylinders or their valves, particularly oxygen**
  - **Substitute oxygen for compressed air**
  - **Use a wrench on a cylinder valve equipped with a hand wheel**

Always vent a pressure or vacuum system to atmospheric pressure ***BEFORE* disconnecting fittings, hoses or valves**

Outline

- Overview
- LLE General laboratory safety policies
- Personal Protection Equipment (PPE)
- Laser Safety
- Mechanical Safety
- Compressed Gas Safety
- ➢ Electrical Safety
- Chemical Safety

Electrical Safety Policies

- **If it is 50 Volts or Greater, it is High Voltage**
- **Guest workers may *not***
  - **Open/close/reset circuit breakers in electrical panels**
  - **Modify electrical distribution services**
  - **Service energized equipment, unless following LLE approved written procedures**

Physiological Effects of Electricity

Effects of Electrical Current* on the Body[3]

Current	Reaction
1 milliamp	Just a faint tingle.
5 milliamps	Slight shock felt. Disturbing, but not painful. Most people can "let go." However, strong involuntary movements can cause injuries.
6–25 milliamps (women)† **9–30 milliamps** (men)	Painful shock. Muscular control is lost. This is the range where "freezing currents" start. It may not be possible to "let go."
50–150 milliamps	Extremely painful shock, respiratory arrest (breathing stops), severe muscle contractions. Flexor muscles may cause holding on; extensor muscles may cause intense pushing away. Death is possible.
1,000–4,300 milliamps (1–4.3 amps)	Ventricular fibrillation (heart pumping action not rhythmic) occurs. Muscles contract; nerve damage occurs. Death is likely.
10,000 milliamps (10 amps)	Cardiac arrest and severe burns occur. Death is probable.
15,000 milliamps (15 amps)	Lowest overcurrent at which a typical fuse or circuit breaker opens a circuit!

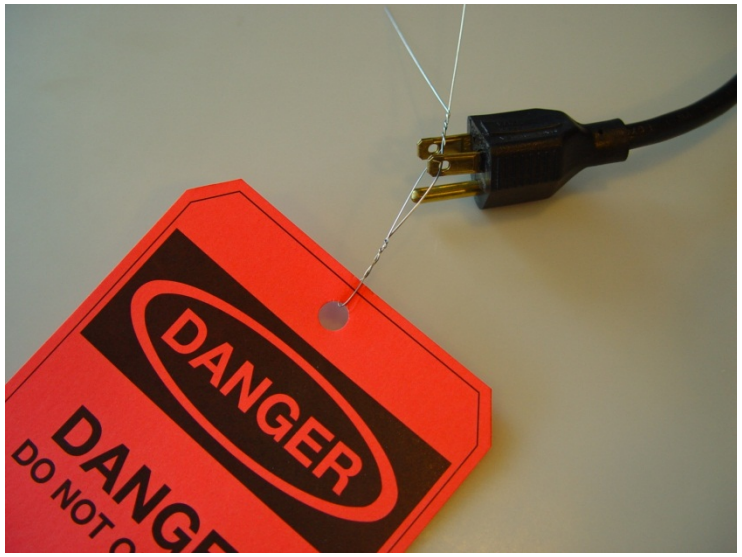
*Effects are for voltages less than about 600 volts. Higher voltages also cause severe burns.
†Differences in muscle and fat content affect the severity of shock.

Several variables influence the severity of electrical injuries

- **Moisture: Dry is better**
  - **Below 600 volts, dry skin is 100× more resistive than damp skin**
- **Contact area: Smaller contact area is better**
  - **Finger contact is higher resistance than a whole hand.**
- **Pressure: Low pressure is better**
  - **Increasing pressure decreases resistance, increases the risk of burn.**
- **Duration: Brief contact is better**
  - **The longer the contact, the more likely the burn.**

LLE Lockout / Tagout Policy

- **LOCKOUT - installation of a physical barrier or removal of a connecting link to prevent operation of component**
- **TAGOUT - placement of tag on breaker, switch, control device or valve stating "DANGER DO NOT OPERATE"**
- **POLICY:**
  - **Immediately notify Supervisor if equipment is suspected of presenting a hazard to personnel or other equipment.**
  - **LLE staff are responsible for ensuring that equipment is properly locked/tagged out and recorded**
  - **Guest workers may not remove "Danger – Do Not Operate" tags**



LLE electrical safety policies

- **Extension cords**
  - **500W maximum (U/R policy)**
  - **May not be connected in series**
- **Equipment used at LLE must be UL certified, or have approval of LLE Electrical Safety Officer**
- **Guest workers may not repair any high voltage (≥ 50V) equipment. Have your LLE supervisor contact the LLE Electronics shop if repairs are needed**

Warm, damaged, frayed or deteriorated cord?

STOP! Seek assistance

Common Sense Practices

- **Allow proper ventilation for power dissipating equipment. Keep air filters clean.**
- **Investigate “hot” or unusual smells around equipment.**
- **Turn off unused equipment (excluding LLE-managed PC’s)**
- **Prior to activation of remote (OUT OF SIGHT) equipment verify clear and secure**
- **Never leave a potentially hazardous situation unattended for ANY REASON**
- **Recognize and mitigate hazards to others. Use simple warning signs to communicate dangers or possible risks**

Ask for help before it is too late!

Outline

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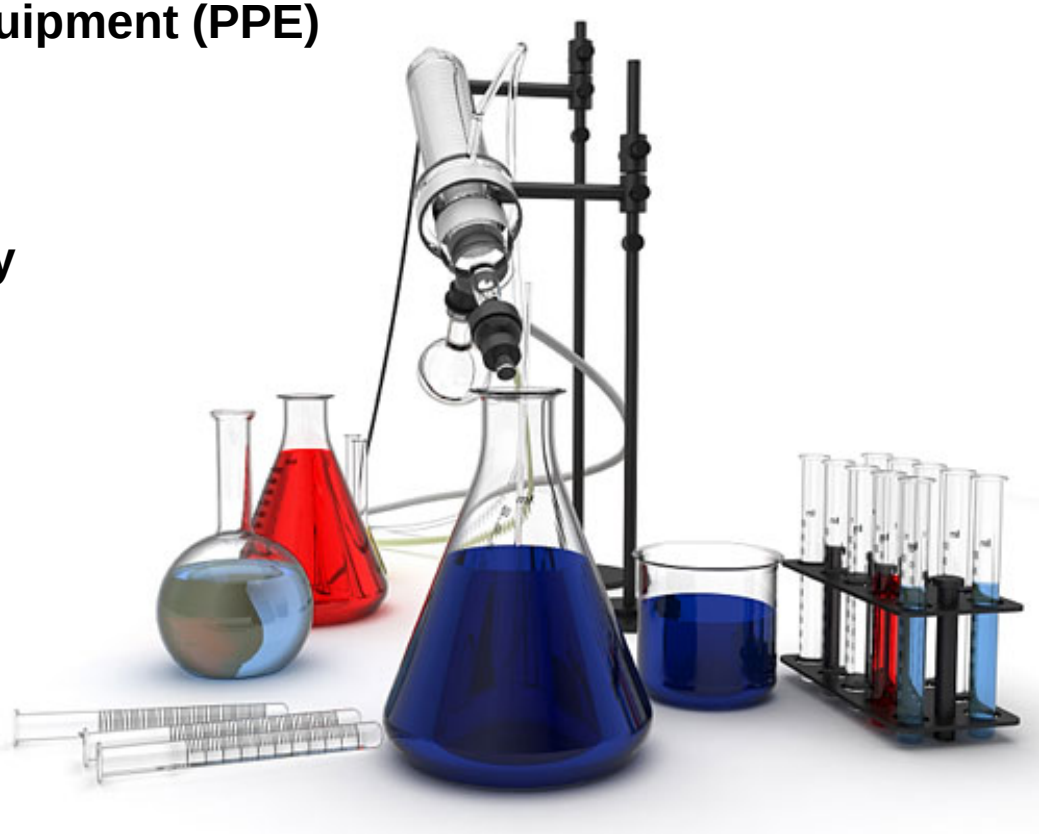


Guest workers have limited authorization to use chemicals at LLE

Persons who complete this training may use only low toxicity, low reactivity, reagents and chemicals in small quantities (< 100 ml) , e.g. Methanol, Isopropyl, Acetone.

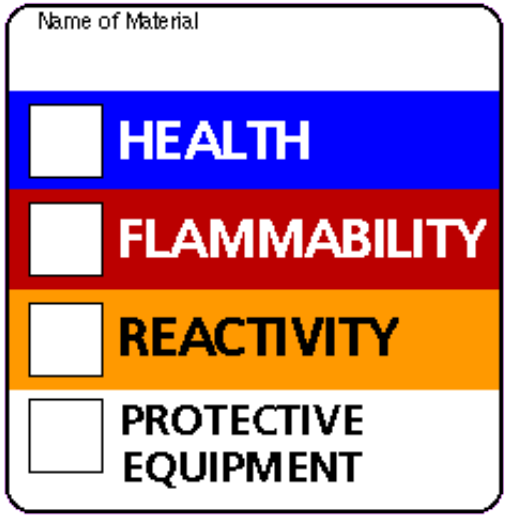
- **Persons needing to perform chemical mixing or processes, or those exceeding above conditions must complete C_001 Chemical safety training**
- **Persons needing to work with materials listed below must complete the training indicated**

Topic	Hazard	Training requirements
Beryllium	CBD, Cancer suspect agent	C_002: Beryllium Safety
Lead	Dust	"Lead Encapsulation Procedure" (V 1.0, 6/10/09)
Formaldehyde	Carcinogen, allergic sensitizer	C_003: Formaldehyde Safety

NFPA and HMIG graphical warning labels provide rapid communication of critical safety information

NFPA

HMIG



PPE categories:
A-K and X

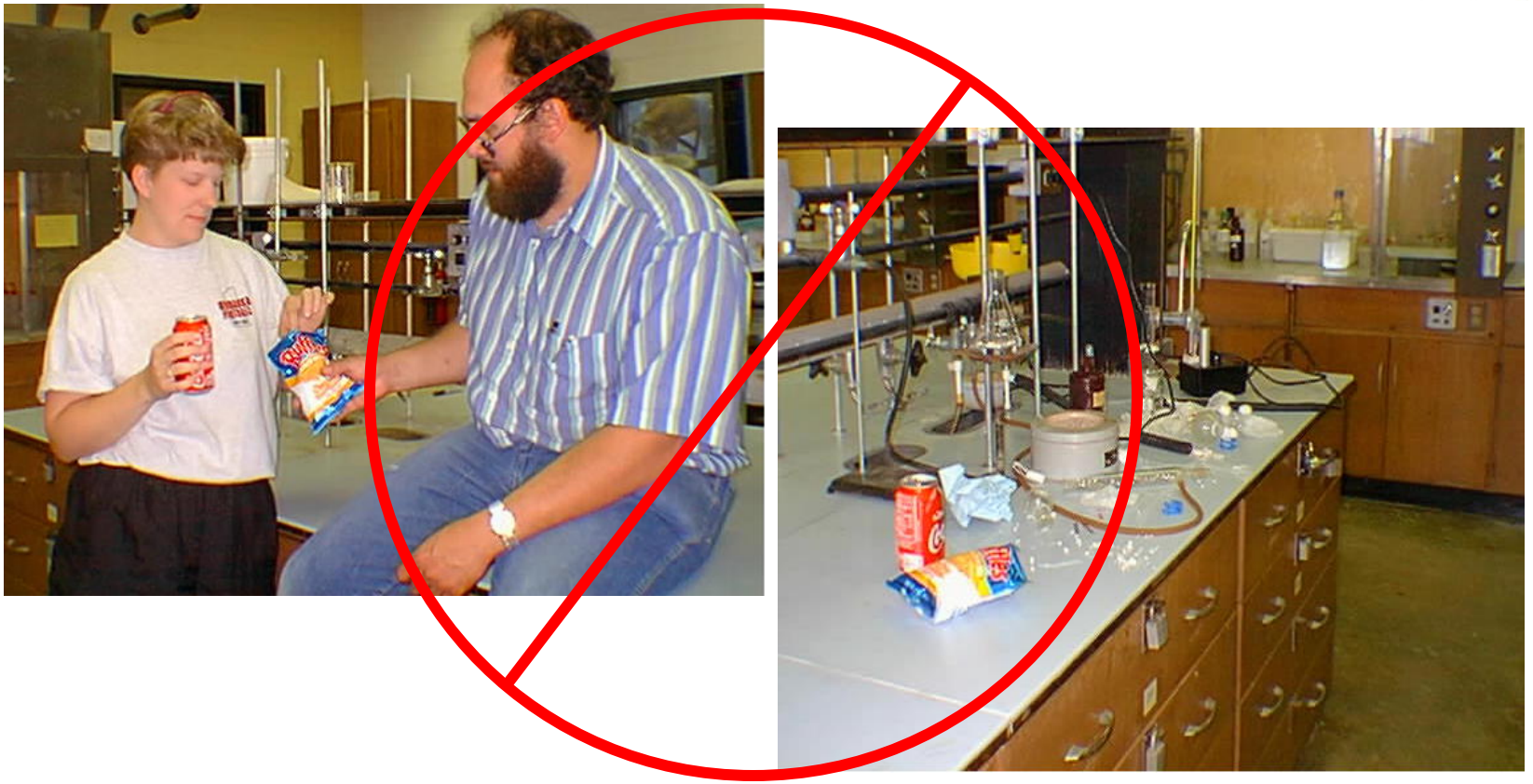
Eye protection and gloves are mandatory for all chemical operations at LLE

Don’t spread contaminants. Remove gloves before touching keyboards, telephones or door handles

Glove holding sample

No Glove on door handle

Food and beverages are prohibited in laboratories



Strictly prohibited by governmental, UR, and LLE regulations and guidelines !

Contact with “sharps” can result in serious injuries

- Razor blades/scalpels
- Broken glass items (including optics)
- Syringe needles (new or used)
- Microscope slides
- Pipettes

- Use ***non-biohazard*** sharps containers (small items) or glass disposal boxes

NEVER put sharps or glass items in the regular trash!

Many waste materials are designated as “hazardous”

- **Batteries** *(toxic, corrosive, reactive)*
  - **lead-acid, mercury, NiCd, NiMH, Li+, AgO**
  - ***alkaline and carbon batteries are excluded***
- **“Sharps”** *(toxic)*
- **“Universal wastes”** *(toxic)*
  - **mercury-containing items (lamps, bulbs, switches, electronics, pressure/vacuum monitors, thermostats)**
- **“E-waste”** *(toxic)*
  - **computers, power supplies, electronics, circuit boards, lasers**
- **Beryllium and other powdered metals** *(toxic, ignitable)*
- **Aerosol cans** *(ignitable, corrosive, toxic)*

Contact your supervisor or a Safety Officer to assist with disposal of hazardous wastes

Summary

- LLE's Safety Officers are available to discuss any questions or concerns you have about safety policies and practices at LLE
- Most Guest Workers can complete this one training module to satisfy all LLE safety training requirements
  - Workers needing access to LaCave or the OMEGA Target Bay must also complete C_002 – Beryllium Safety Training
- This presentation does not cover radiation safety training. Interested persons must contact the Radiation Safety Officer for guidance.
- Workers who engage in laboratory activities at the Laboratory for Laser Energetics (LLE) need to understand and follow site-specific safety policies
- All workers must read and follow instructions on signs when entering a laboratory space
- The Laser Facility Manager and Safety Officers must authorize operation of any equipment (e.g., laser, machine) having compromised Engineering Controls (interlocks, safety enclosures, etc.)