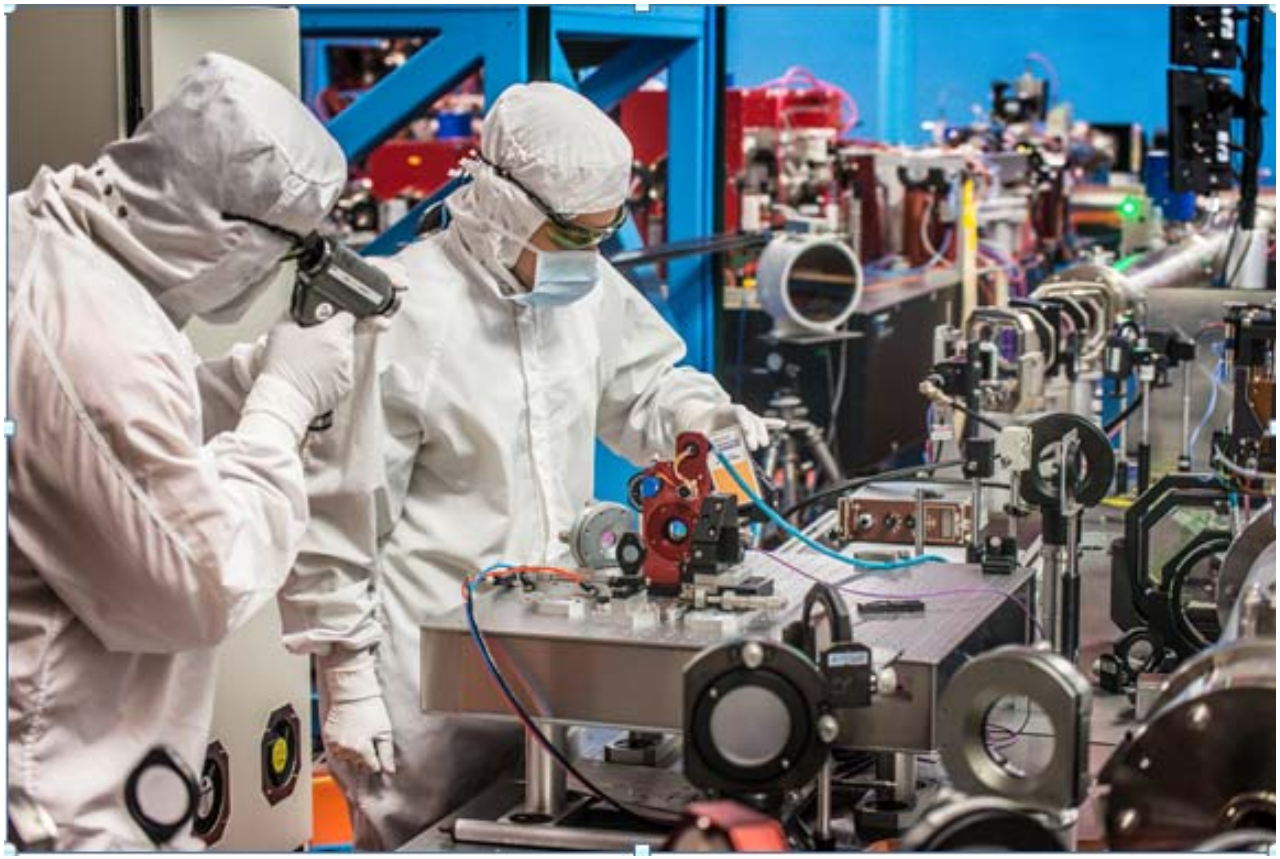
L_003 Laser Instrument Specialist Training



Laser Operators aligning complex laser systems

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Training and associated privileges

- L_001 training is required to enter a laboratory where class 3B or 4 lasers are in use
  - Not allowed to operate class 3B or 4 lasers
- Laser Operator qualification cards are used to certify a person to operate a class 3B or 4 laser using established process
- L-003 training is required to integrate or modify a laser or laser system
  - Laser Instrument specialists are permitted to perform advanced troubleshooting and maintenance

There are four primary responsibilities associated with being a Laser Instrument Specialist

- Completing the design and/or integration of Class 3B and Class 4 laser systems in accordance with safety policy.
  - Applies when a laser is purchased, imported, or relocated within the building
  - Applies during design modifications
- Oversight of the training and operations to ensure that the lasers are run in a safe manor
- Participating in safety reviews when requested by the LSO
- Managing the intentional deactivation/decommissioning of a laser system

Lasers and Intense Light Sources are regulated by Instruction 6200*

- All Laser System Hazards shall be analyzed by the LSO who shall help the Instrument Specialist develop an integration plan to mitigate those hazards
- The Laser Instrument Specialist is responsible for contacting the LSO for hazard analysis during laser equipment selection
  - Select the lowest operating power that can effectively accomplish the task to simplify integration
- After selection, the Laser Instrument Specialist shall provide details in form S-SA-M-066 for the laser inventory
- A safety inspection is required in advance of turning on a new laser. Form S-SA-M-067 will be used for this inspection

Components that modify the laser beam (provide gain or modify the spectrum) must be integrated with the same process as a laser source

*LLE Instruction 6200 (S-SA-M-064)

Laser selection or specification begins the integration process for lasers

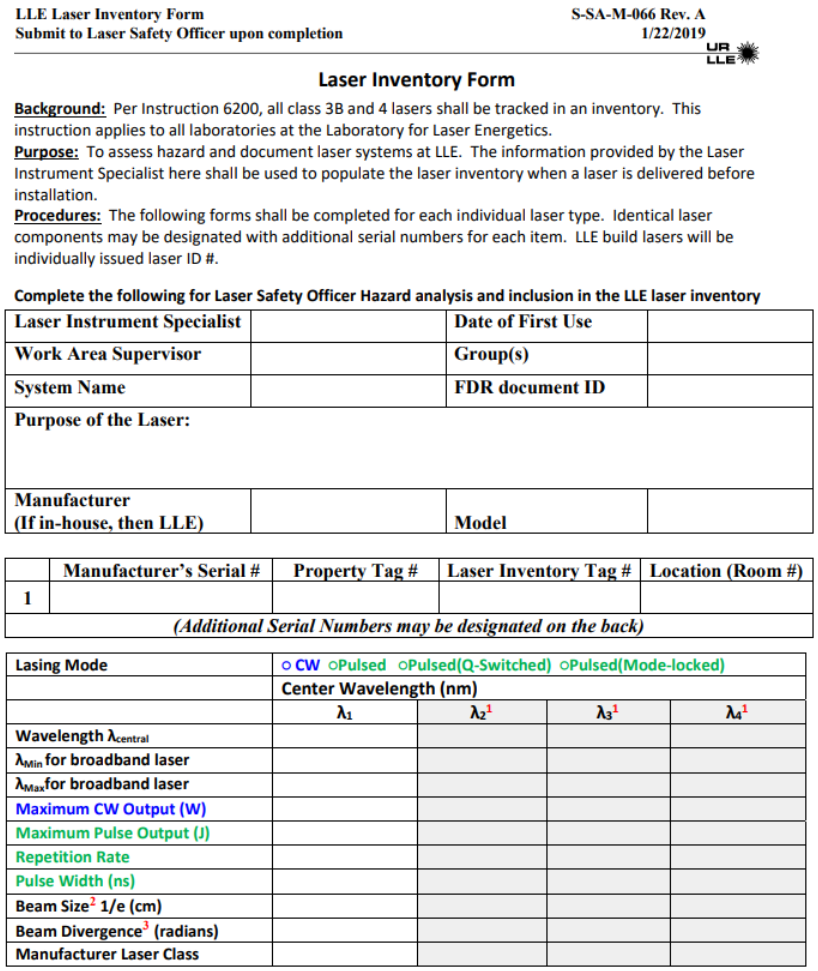
- Contact LSO for hazard analysis during selection (project definition) phase
  - Hazard is defined by: wavelength(s), power for CW system (or energy, pulse width, and repetition rate for pulsed system)
- With increasing hazards, the cost and effort to design and implement necessary engineering and administrative controls will increase
  - Class 1, 1M, 2, 2M, and 3R lasers are not to be pointed at a person's eyes. No additional protocol is required
  - Class 3B and 4 lasers require signs, laser protective eyewear (LPE), interlocks, operating procedures, etc.
  - Class 4 lasers can also require extensive enclosures, skin protection, closed access, etc.
- The hazard calculations are for guidance during the selection process

Laser system design is required for all Class 3B and Class 4 lasers

- Even commercial lasers will require some level of system design before being operated
- After the laser is selected (commercial vendor) or specified (for LLE fabrication), the design process for the system will begin
  - Large design processes are carried out following LLE inst. 7700
  - Smaller systems will be designed by the laser instrument specialist with the input of the area supervisor and laser safety officer
- Design of interlocks, barriers, procedures, etc. will be commensurate with hazard level (Hardware must be purchased as part of project or by use of group funds)
- Laser Protective Eyewear (LPE) requirements will be determined
- Laser signs will be modified as required

The Laser Inventory Form collects information for hazard analysis and LLE records

- This form documents basic characteristics of the laser
- Tunable or broadband lasers are handled with λ_{min} and λ_{max}
- The form allows specification of up to 4 wavelength ranges
- The LSO will perform a formal hazard analysis calculation using data in this form
- Use the reverse side if multiple lasers of the same characteristics are being purchased



LLE Laser Inventory Form
Submit to Laser Safety Officer upon completion

S-SA-M-066 Rev. A
1/22/2019

Laser Inventory Form

Background: Per Instruction 6200, all class 3B and 4 lasers shall be tracked in an inventory. This instruction applies to all laboratories at the Laboratory for Laser Energetics.
Purpose: To assess hazard and document laser systems at LLE. The information provided by the Laser Instrument Specialist here shall be used to populate the laser inventory when a laser is delivered before installation.
Procedures: The following forms shall be completed for each individual laser type. Identical laser components may be designated with additional serial numbers for each item. LLE build lasers will be individually issued laser ID #.

Complete the following for Laser Safety Officer Hazard analysis and inclusion in the LLE laser inventory

Laser Instrument Specialist		Date of First Use	
Work Area Supervisor		Group(s)	
System Name		FDR document ID	
Purpose of the Laser:			
Manufacturer (If in-house, then LLE)		Model	

	Manufacturer's Serial #	Property Tag #	Laser Inventory Tag #	Location (Room #)
1				
(Additional Serial Numbers may be designated on the back)				

Lasing Mode	○ CW ○Pulsed ○Pulsed(Q-Switched) ○Pulsed(Mode-locked)			
	Center Wavelength (nm)			
	λ_1	λ_2[1]	λ_3[1]	λ_4[1]
Wavelength $\lambda_{central}$				
λ_{Min} for broadband laser				
λ_{Max} for broadband laser				
Maximum CW Output (W)				
Maximum Pulse Output (J)				
Repetition Rate				
Pulse Width (ns)				
Beam Size[2] 1/e (cm)				
Beam Divergence[3] (radians)				
Manufacturer Laser Class				

Use a Laser Inventory Form (S-SA-M-066) to submit laser characteristics for inclusion in the laser inventory

The laser inventory is available on the web

- The goal of the laser inventory is to uniquely track the device from inception to decommissioning.
  - Attach user manuals and other reference materials
  - Update regularly when contacts change
  - Location can be updated quickly (safety inspection often required)
  - Status
- Sort list to review lasers assigned to you (or all lasers in a specific room)

Laser Inventory is linked on the safety zone

	Laser Safety		
L_001	Laser Safety Training	Quiz	• LLE Instruction 6200: Laser Safety Policy and Procedures • Laser Operator Qualification Card • Laser Inventory Form • Laser Activation Checklist • LLE Laser Inventory (password required) • U of R Laser Safety for Research and Teaching Laboratories • New York State Regulation (use Firefox) • Laser Institute of America • DOE Laser Safety Task Group • Laser Safety Facts • Laser Class Descriptions
	Laser Hazard Analysis Software Instructions/Tutorials		

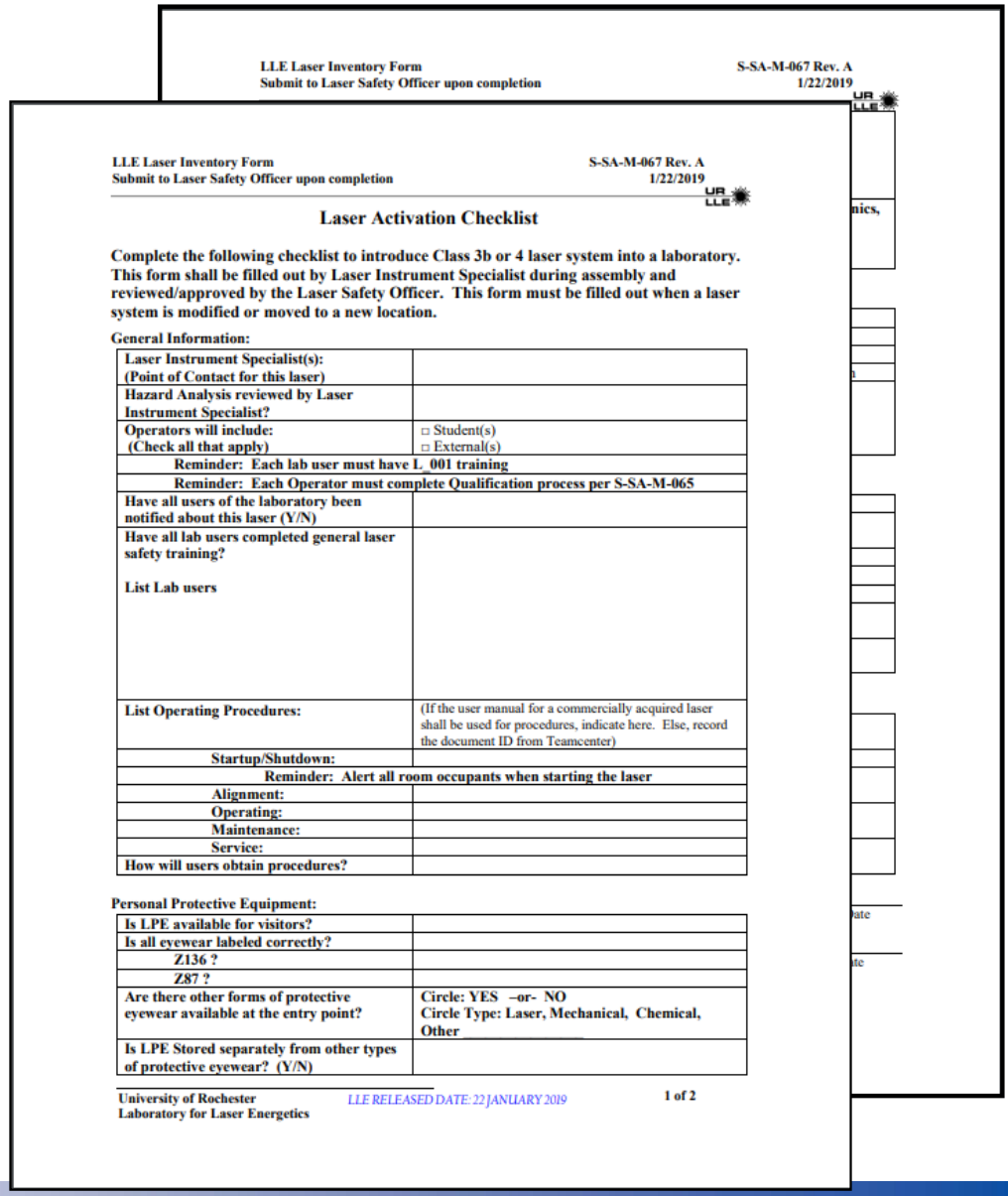
The laser inventory does require registration and is password protected

Fabrication may begin as components arrive, but the laser shall not be activated until a safety inspection is complete

- Fabrication shall be in accordance with design and using all safety principles
- When you are ready to generate light, contact the LSO to schedule a safety inspection
  - Schedule inspections in advance to avoid delays
  - The LSO will bring a copy of the hazard analysis and a Laser Activation Checklist (S-SA-M-067)
  - If all safety equipment is in place as designed, the inspection takes only a few minutes

The Laser Activation Checklist verifies that all safety measures are in place

- Two page form will ensure that all the safeguards are checked
  - Lab users aware
  - Operating procedures in place
  - PPE available
  - Interlocks & signs functional
  - Beam paths avoid exposure risk
- It is suggested that you print out the form and review during fabrication to ensure compliance
- Best practices will be reinforced during the inspection
- Activation may then proceed



LLE Laser Inventory Form
Submit to Laser Safety Officer upon completion
S-SA-M-067 Rev. A
1/22/2019

Laser Activation Checklist

Complete the following checklist to introduce Class 3b or 4 laser system into a laboratory. This form shall be filled out by Laser Instrument Specialist during assembly and reviewed/approved by the Laser Safety Officer. This form must be filled out when a laser system is modified or moved to a new location.

General Information:

Laser Instrument Specialist(s): (Point of Contact for this laser)	
Hazard Analysis reviewed by Laser Instrument Specialist?	
Operators will include: (Check all that apply)	□ Student(s) □ External(s)
Reminder: Each lab user must have L_001 training	
Reminder: Each Operator must complete Qualification process per S-SA-M-065	
Have all users of the laboratory been notified about this laser (Y/N)	
Have all lab users completed general laser safety training? List Lab users	
List Operating Procedures:	(If the user manual for a commercially acquired laser shall be used for procedures, indicate here. Else, record the document ID from Teamcenter)
Startup/Shutdown:	
Reminder: Alert all room occupants when starting the laser	
Alignment:	
Operating:	
Maintenance:	
Service:	
How will users obtain procedures?	

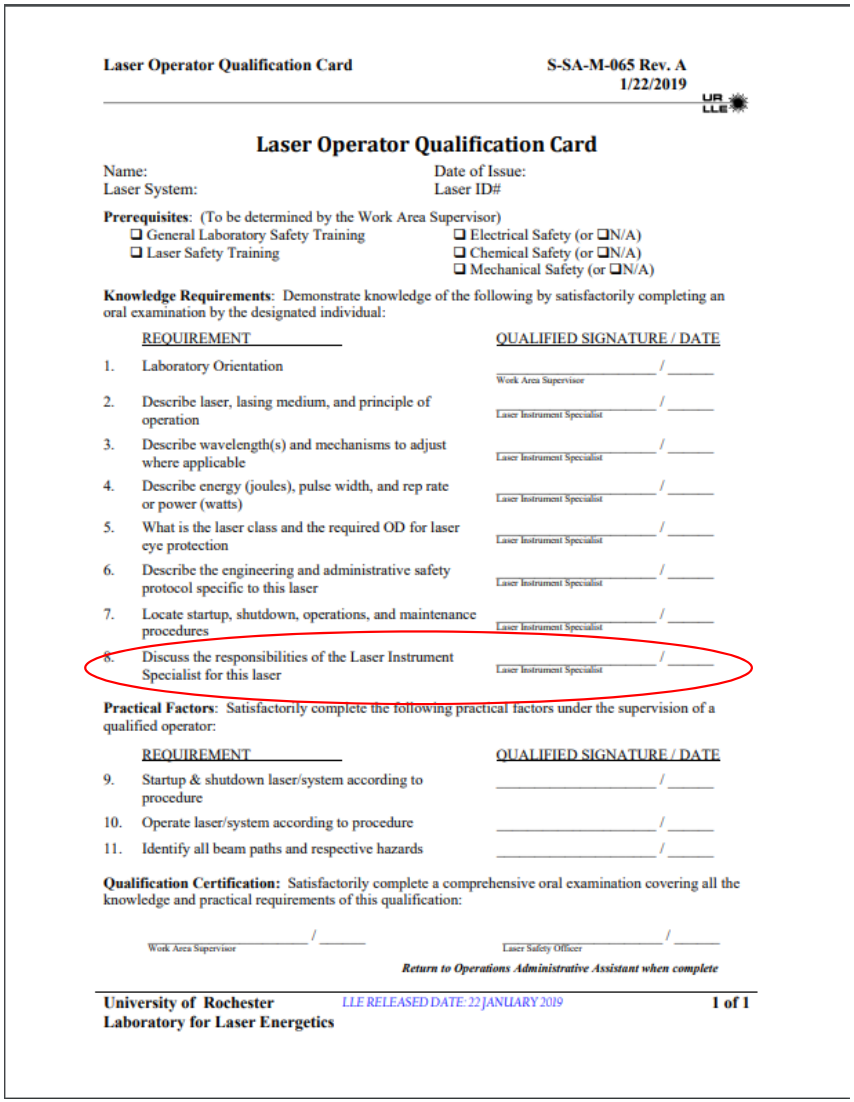
Personal Protective Equipment:

Is LPE available for visitors?	
Is all eyewear labeled correctly?	
Z136 ?	
Z87 ?	
Are there other forms of protective eyewear available at the entry point?	Circle: YES –or- NO Circle Type: Laser, Mechanical, Chemical, Other
Is LPE Stored separately from other types of protective eyewear? (Y/N)	

University of Rochester
Laboratory for Laser Energetics
LLE RELEASED DATE: 22 JANUARY 2019
1 of 2

The Laser Instrument Specialist is responsible for training laser operators

- **Laser Instrument Specialists who build the system do not fill out a qual card (fabrication is expertise)**
- **You must train others who will operate the laser system**
- **Your responsibilities:**
  - **oversight of the system**
  - **all modifications must be managed by you**
  - **Participate in safety reviews**
- **If you cannot support the laser system, <u>hand off responsibilities to a trained operator</u>**



Laser Operator Qualification Card S-SA-M-065 Rev. A 1/22/2019

Laser Operator Qualification Card

Name: Date of Issue:
Laser System: Laser ID#

Prerequisites: (To be determined by the Work Area Supervisor)
- ❑ General Laboratory Safety Training
- ❑ Laser Safety Training
- ❑ Electrical Safety (or ❑N/A)
- ❑ Chemical Safety (or ❑N/A)
- ❑ Mechanical Safety (or ❑N/A)

Knowledge Requirements: Demonstrate knowledge of the following by satisfactorily completing an oral examination by the designated individual:

	REQUIREMENT	QUALIFIED SIGNATURE / DATE
1.	Laboratory Orientation	Work Area Supervisor
2.	Describe laser, lasing medium, and principle of operation	Laser Instrument Specialist
3.	Describe wavelength(s) and mechanisms to adjust where applicable	Laser Instrument Specialist
4.	Describe energy (joules), pulse width, and rep rate or power (watts)	Laser Instrument Specialist
5.	What is the laser class and the required OD for laser eye protection	Laser Instrument Specialist
6.	Describe the engineering and administrative safety protocol specific to this laser	Laser Instrument Specialist
7.	Locate startup, shutdown, operations, and maintenance procedures	Laser Instrument Specialist
8.	Discuss the responsibilities of the Laser Instrument Specialist for this laser	Laser Instrument Specialist

Practical Factors: Satisfactorily complete the following practical factors under the supervision of a qualified operator:

	REQUIREMENT	QUALIFIED SIGNATURE / DATE
9.	Startup & shutdown laser/system according to procedure	
10.	Operate laser/system according to procedure	
11.	Identify all beam paths and respective hazards	

Qualification Certification: Satisfactorily complete a comprehensive oral examination covering all the knowledge and practical requirements of this qualification:

Work Area Supervisor / Laser Safety Officer /

Return to Operations Administrative Assistant when complete

University of Rochester *LLE RELEASED DATE: 22 JANUARY 2019* **1 of 1**
Laboratory for Laser Energetics

The LSO must oversee some tasks

Decommissioning: A Laser must be in the inventory until it is rendered unusable. It cannot be disposed of until it cannot function

- **Do not simply throw it in the trash**
- **Additional safety officers could be required (i.e., disposal of chemical dye)**

Export to another researcher: If the laser will leave LLE, additional laws must be followed. These laws are expected to change so it will require research to determine all of the necessary steps at the time this occurs

Do not take lasers home!

LLE is beginning the process of interlocking all Class 3B and 4 lasers to the room signs

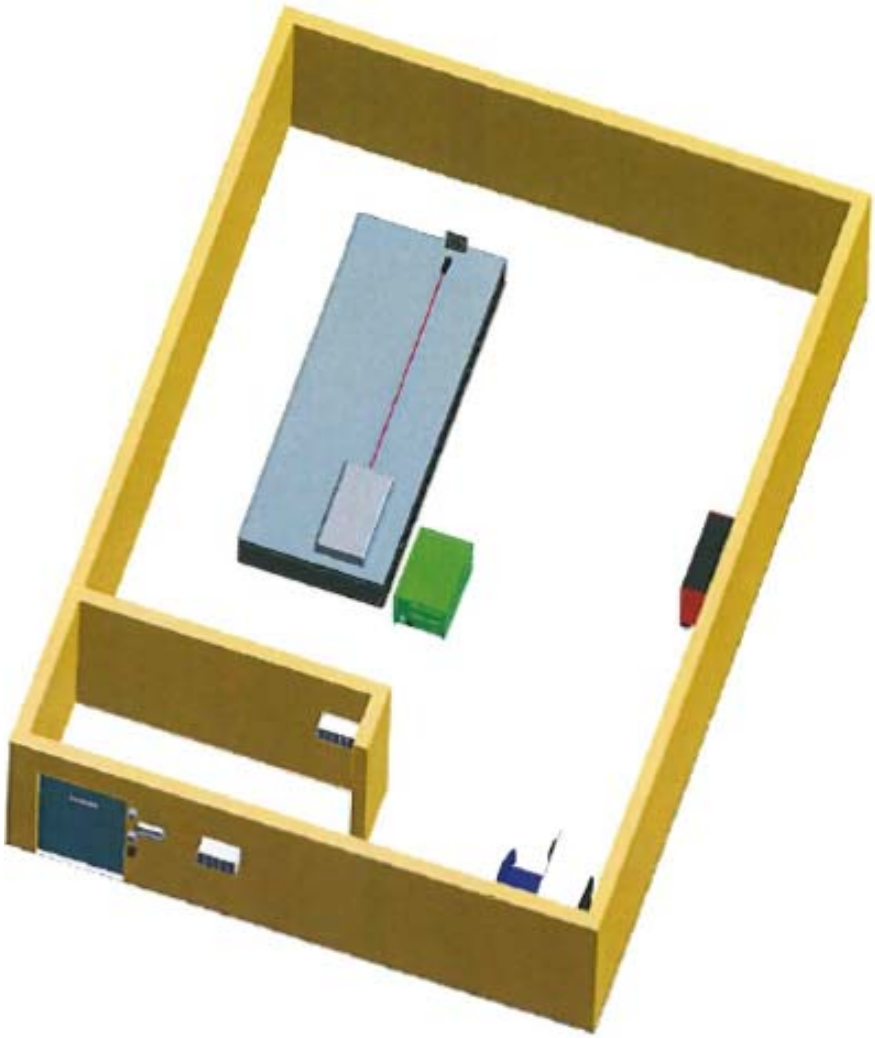
- Room interlocks are designed to prevent the activation of the laser until the appropriate door signs are illuminated
- Interlocks disable the laser in the event of a fire alarm (so that emergency responders can safely enter the room)
- E-Stop buttons will be placed at the entry and around the room to interrupt the interlock and safe the laser(s)
- Legacy rooms (where laser door signs are activated manually/ procedurally before the laser can propagate) interlock integration requirements will be evaluated on a case by case basis.
- Interlocks are mandatory for all new room installations of class 3b and 4 lasers

Other Laser Interlocks can be Useful in some areas

- The LSO may suggest an enclosure. Enclosures can be interlocked to prevent laser propagation within a room (avoiding room signs)
  - These interlocks stop the laser if the enclosure is open (or only when the door signs are not appropriate for the enclosed source)
- Chief Safety Officer (CSO) will participate in the design.
  - Only the CSO can authorize bypassing an interlock (this can be through a released procedure)
- Interlock design could also include
  - Mechanical Engineering for hardware design
  - Electrical Engineering for circuit design & wiring
  - Facilities for room infrastructure

Laser room layout is guided by ANSI standard

- **Barrier prevents laser from leaving room and entering "common" space**
  - **New barriers are constructed by the facilities group**
- **Entry area protects individual upon entry, provides a location to put on PPE. <u>This is not a place for meetings!</u>**
- **Operator care is required to ensure beams are blocked and stay on optical table**
- **At LLE, LPE is required to pass the active sign. The sign is at the entrance to the laser environment**



More information about Laser Hazard Calculations (performed by the LSO)

- ANSI Z136.1 regulates the Maximum Permissible Exposure (MPE) for the eye. The MPE is a fluence (J/cm^2 or W/cm^2) formulaically determined by wavelength & pulse width/frequency.
- The required OD is calculated as the attenuation required to bring beam energy below the MPE
  - It is assumed that the full laser output enters the eye regardless of beam size
  - The value is rounded up to an integer
- When broadband light is present, the hazard calculations will be performed at each wavelength in the band
- Tunable lasers require special attention because shifts in wavelength can dramatically change the LPE requirements. Nominal calculations will be based on the design wavelength(s)

Other considerations can be applied as needed

- **Beam Size: When the beam is much larger than the eye (and focusing elements are not present), beam size can be helpful for determining protocol.**

- **High Power beams: If required OD is greater than 7, additional engineering and administrative controls will be established because LPE is not labeled/trusted to provide protection from high power**
  - **Eyewear rate of absorption inadequate to provide protection**
  - **Alignment work at lower energy is preferred**
  - **Alignment at high energy will require careful planning and approved procedures. The procedures must be executed to ensure beams are not directed toward people**

Diffuse reflection hazard will be included in Class 4 laser calculations

- A diffuse reflector is analyzed like a point source with radiating beam pattern (energy distribution approximated by inverse square law)
- Increasing the distance from the diffuse reflector decreases the hazard
- The Nominal Hazard Zone (NHZ) is the distance from the point source where fluence is less than the MPE assuming a perfect distribution of energy.
- The NHZ is particularly relevant to alignment activities
  - Exposure can be quite long (cumulative exposure effects can occur)
  - Beware using a “target” that is not a diffuse reflector. Many common alignment implements are not perfect diffuse surfaces (laminated alignment cards)
- Diffuse reflections are not a risk when wearing the prescribed LPE. Do not remove your LPE to view an alignment "spot"

Skin hazards will be calculated for class 4 lasers

- Skin hazards begin to be a concern in class 4 lasers. Here is one example of calculation results:
  - A 2 J IR laser (2ns pulses@1064nm) requires a OD2 protection for skin
  - Frequency double the laser to 532nm and energy of 1J will require an OD2 protection
  - Frequency triple the laser to 355nm and an energy of 0.5 J will require OD4 protection
- ANSI Z136.1 gives a formula for skin hazard using a 3.5mm aperture size and assumes that all energy is concentrated into that spot size
- Use low energy alignment energies as a primary defense against hazardous skin exposures
- Enclosures, lab coats, and laser protective gloves may also be warranted in your system

Brief overview of past LLE incidents involving lasers

IR # is a hyperlink to the incident report

Incident 275: Laser Integration is critical to our safe laboratory setting

- Activation of a dye cell occurred without completing the design process and arranging the standard laser safety protocol (including laser signs). The dye cell shifted the wavelength of light by ~30nm
- Each laser dye will create a unique spectrum of laser pulse. This effectively means that changing the dye material is activating a new laser source requiring a fresh hazard mitigation calculation and plan (signs and eyewear)
- The initial laser request was insufficient for hazard analysis, but the details were lost in the planning process

Small changes in the wavelength of light (~30nm) can dramatically change the necessary protective eyewear

Incident 256: Laser Integration is critical to our safe laboratory setting

- **Activation of a frequency conversion stage occurred without completing the design process and arranging the standard laser safety protocol (including laser signs).**
- **No hazard analysis was performed. Operating procedures were not updated and other users of the room were not informed.**
- **Another user entered the room with LPE that satisfied the illuminated signs, but did not protect against 532nm light and was startled to observe bright green light.**

Failure to plan for laser integration endangers other people

Incident 184: Class 3B laser substituted for laser alignment

- A diagnostic alignment was conducted using a class 3B (10mW) laser instead of a class 3R (<5mW) laser originally proposed
- The technicians had difficult performing the operation because of the brightness. When this was reported, management realized that the wrong laser had been used.
- The human eye is very sensitive to green light, which can be uncomfortable to view even if the power is not immediately hazardous. Other wavelengths may be dangerous, even when they are not uncomfortable to view
- Fortunately, the beam was scattered from a surface that was far enough from the technicians to avoid injury. Reflection properties can vary greatly depending on the material characteristics

Carefully review laser equipment before starting a task. Seek approval before deviating from the plan

Incident 153: Exposure during work

- The laser operator was troubleshooting a subsystem and leaned into the beam path for an adjacent diagnostic system. The operator sustained a permanent eye injury
- Operator was wearing appropriate LPE. Beam must have entered either the side or top of the laser glasses

Use barriers (beam tubes or chains) to prevent personnel from forgetting hazardous laser fluence in any space that a person may place their head.

Periscopes and elevation changes for the beam are a contributing cause of many DOE reported incidents

LPE is the last line of defense. Do not assume that LPE is failure proof.

Incident 48: Mechanical Flipper deflects beam into eye

- **While working on a laser system, the operator redirected the beam with a flipper. The arrangement of the flipper resulted in the beam being redirected into the operators face causing a permanent eye injury**
- **Laser beams can be easily reflected into personnel space. Selection of components, especially two-state positioning devices, must consider the beam path in each state, and during transition**

Manage beam reflections carefully in design and construction.

Remember that other items on your hands can also reflect a beam into a dangerous space. Remove watches and jewelry to avoid unintended reflections

Complacency

- IR 15: Employee forgot to exchange normal prescription eyewear for Laser Protective eyewear before entering the class 4 laser environment
  - Fortunately, no injury was sustained
- IR 274: unintentional laser energy in a walkway during system shot
  - Fortunately, no injury was sustained

Diligence is required and complacency must be avoided. Create a culture of best practices, diligent LPE use, and watching each other's backs.

- IR 265: High laser output in the presence of a radio transmitter (laser failure caused hazardous output from a class 3R laser). Attentive operator quickly realized the issue and stopped work.

Questions?

1. Visit the LLE Safety Zone ”*Training*" tab
   http://safety.lle.rochester.edu/520_training/presentations.php
2. Read the L_003 Laser Instrument Specialist Training presentation

3. Complete and submit the L_003 quiz

- Any comments on this presentation and/or the on-line quiz can be recorded at the end of the quiz in the comment box and be submitted with your answers