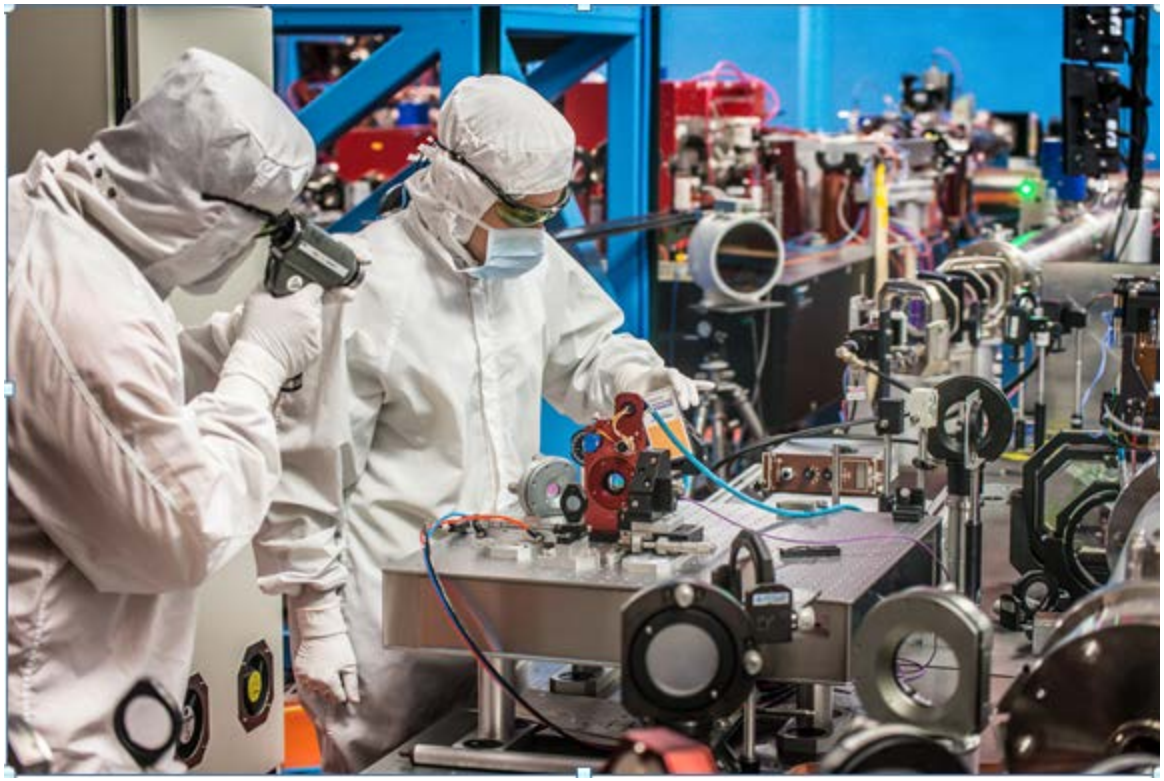
Laser Instrument Specialist Training



Laser Operators aligning complex laser systems

Jason Puth
Laser Safety Officer (LSO)
Laboratory for Laser Energetics (LLE)
University of Rochester

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.
  - Includes purchased lasers and transfers from other institutions
  - Includes tracking design modifications and relocations for a previously approved laser
- Participating in the training of operators including the handoff of Laser Instrument Specialist responsibilities for a laser when necessary
- Participating in safety reviews when requested by the LSO
- Managing the intentional decommissioning of a laser system when necessary

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
  - Always try to specify and select the lowest operating class & power that can effectively accomplish the task
- 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, or relocated, 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

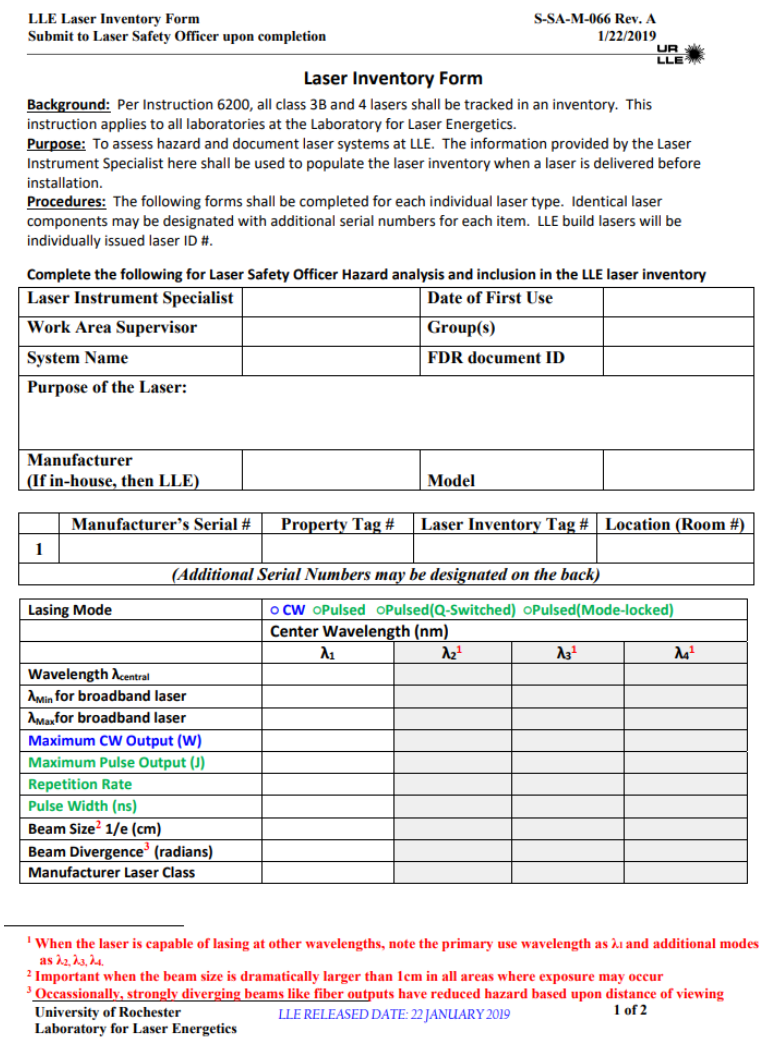
- **Contact LSO for hazard analysis during selection (project definition) phase**
  - **Hazard is defined by: wavelength(s), power for CW system (or energy, pulse width, and repetition rate for pulsed system)**
- **Hazards increase the cost and effort to design and implement necessary engineering and administrative controls**
  - **Class 1, 1M, 2, 2M, and 3R lasers do not require engineering controls**
- **Hazard calculations are for guidance and information will be checked again later**

Laser system design will be 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
  - The design review process is carried out according to Inst 7700
- Laser safety shall be reviewed at each stage of design
- Design of interlocks, barriers, procedures, etc. will be commensurate with hazard level
- Laser Protective Eyewear (LPE) requirements will be determined.
- Next Step: Complete a Laser Inventory Form (S-SA-M-066) so that the database is up to date with all information

Laser Inventory Form

- 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 harmonics or up to 4 wavelength ranges
- The LSO will perform a formal hazard analysis calculation using data in this form
- The LSO will enlist you as an approver for the hazard analysis



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				

[1] When the laser is capable of lasing at other wavelengths, note the primary use wavelength as λ_1 and additional modes as $\lambda_2, \lambda_3, \lambda_4$.
[2] Important when the beam size is dramatically larger than 1cm in all areas where exposure may occur
[3] Occassionally, strongly diverging beams like fiber outputs have reduced hazard based upon distance of viewing

University of Rochester
Laboratory for Laser Energetics

LLE RELEASED DATE: 22 JANUARY 2019

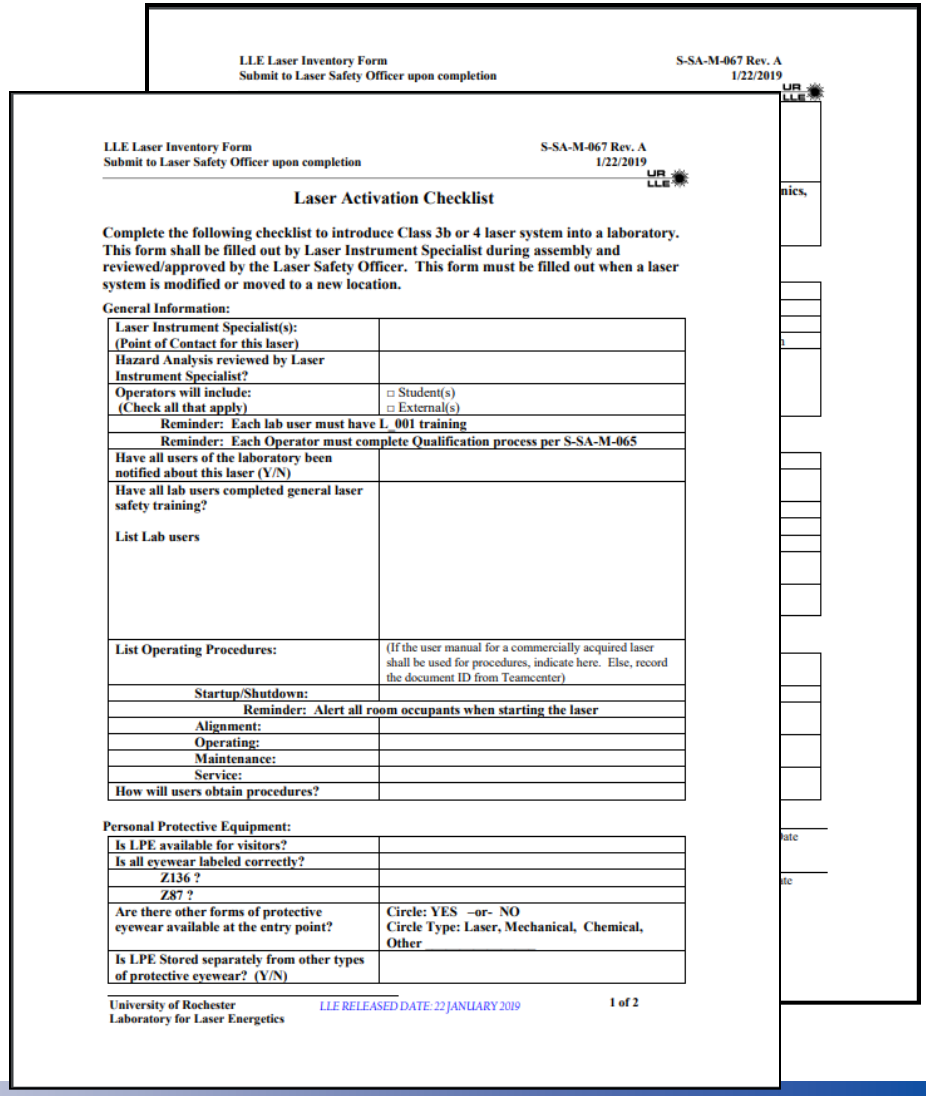
1 of 2

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 hardware is in place as designed, the inspection takes only a few minutes**
- **Activation may then proceed exclusively by the Laser Instrument Specialist**
- **Operator training per S-SA-M-065 (Laser Operator Qualification Card) is required before additional personnel are permitted to participate.**

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

- 2 page form will ensure that all the normal items are inspected
- It is suggested that you print out the form and review during fabrication to ensure compliance
- Best practices will be reinforced during the inspection
- This is the only form required when relocating a laser system (remember that the laser should not be turned on in a new location until safety review is complete)



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)	

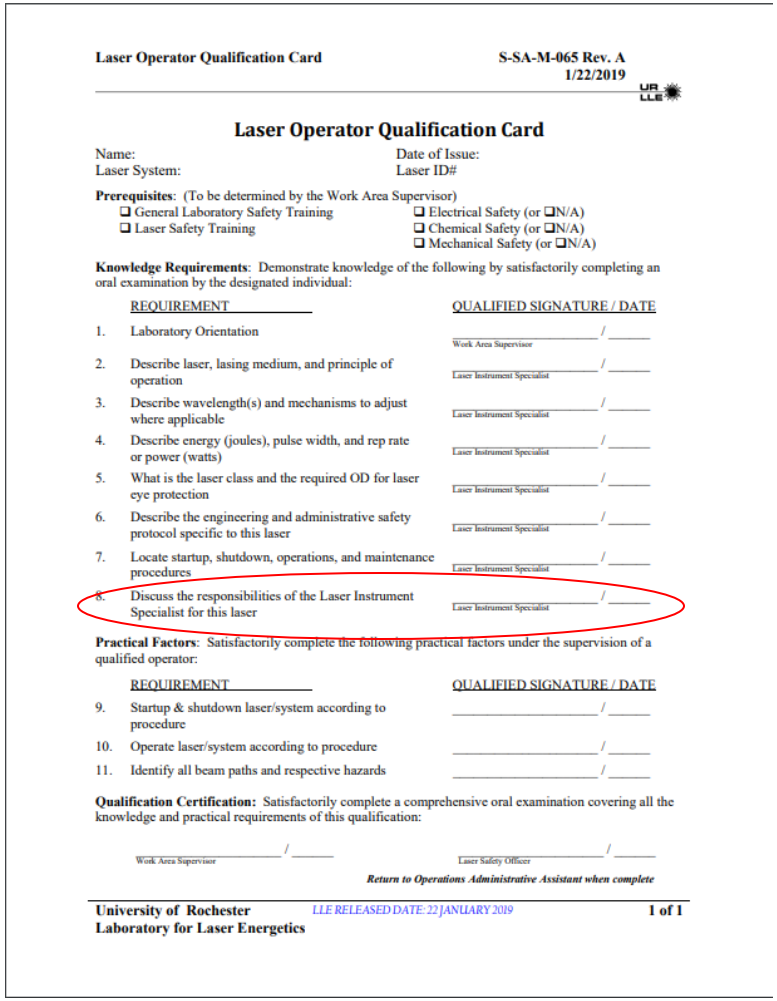
University of Rochester
Laboratory for Laser Energetics

LLE RELEASED DATE: 22 JANUARY 2019

1 of 2

Each Laser Operators must go through the training process prescribed by the qual card

- **Knowledge Factors: The Laser Instrument Specialist is responsible for training laser operators. This includes making sure users understand the laser design, integral safety features, and principles of operation.**
- **Practical factors: Any qualified operator may sign when operator has demonstrated proficiency**
- **The Work Area Supervisor authorizes**
- **A Laser Safety Officer will certify the completion**
- **Return to Operations Admin Assistant for record keeping**



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

Each laser system must have a Laser Instrument Specialist

- **If you can no longer serve in this capacity, inform the LSO and the area supervisor. The LSO and work area supervisor will assign a new Laser Instrument Specialist**
- **This can happen for a number of reasons: Promotion, new project demands, retirement, etc.**
- **Database will be updated**
  - **LSO will know who to direct questions to**

The LSO will need to be involved with a few 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

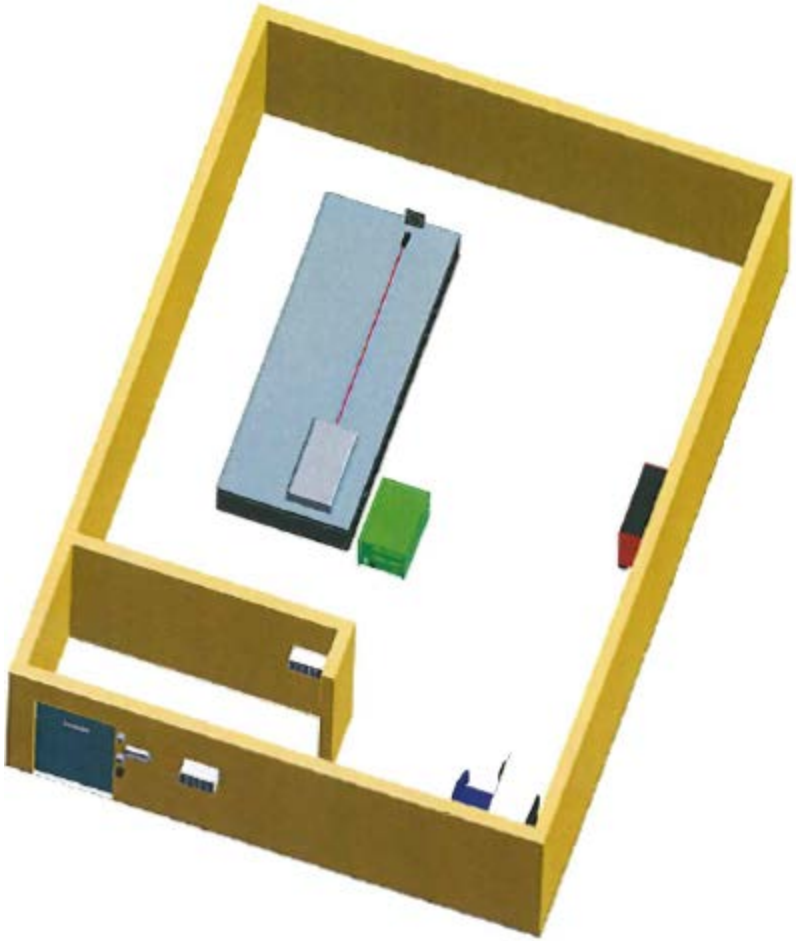
Do not take lasers home!

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

- **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 around the room to interrupt the interlock and safe the laser**
- **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**

Laser room layout is guided by ANSI standard

- **Barrier prevents laser from leaving room and entering “common” space**
- **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**



Reference Slide for Laser Hazard Calculations

- **ANSI Z136.1 determines 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**
  - **It is assumed that the full laser output is reflected toward your eye**
  - **It is assumed that the fluence is evenly distributed in the eye's aperture (not based upon the laser spot size)**
  - **Only when the beam is much larger than the eye (and focusing elements are not present) will laser spot size be taken into consideration, but only for propagation in a walkway (not OD of LPE)**
- **The ratio of the MPE to the beam energy/power determines the OD requirement. The requirement is rounded up to an integer value**
  - **Broadband or tunable lasers will have the same OD requirement for all possible wavelengths**

Diffuse reflection hazard is relevant to alignment practices

- 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
- Analysis of diffuse reflector is relevant to alignment activities
  - Distance is usually moderate, but exposure can be quite long
  - Beware using a “target” that is not a diffuse reflector. Many common alignment implements are not perfect diffuse surfaces
- Calculation can be important for using curtains between workspaces
- The eyewear specified on door signs is adequate for diffuse reflection protection.

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**
  - **The same laser (frequency doubled to 532nm) and energy of 1J will require an OD2 protection**
  - **The same laser (frequency tripled to 355nm) and an energy of 0.5 J will require OD4 protection**
- **Like eye hazard, ANSI Z136.1 gives a formula for skin hazard using a 3.5mm aperture size and the assumption 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 gloves may also be warranted in your system**

Brief overview of past LLE incidents involving lasers

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

- **An engineer installed and operated a 1ω to 2 ω (1053nm{IR} to 532nm{Green}) frequency conversion stage 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 room user entered the room with LPE that satisfied the illuminated signs, but did not protect against 532nm light.**
- **The user 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 260: Inadequate laser barriers and improper use of laser warning signs by lab workers**
  - **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.

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

- New employees/students – after receiving your graded quiz, contact the LSO for an orientation

- 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