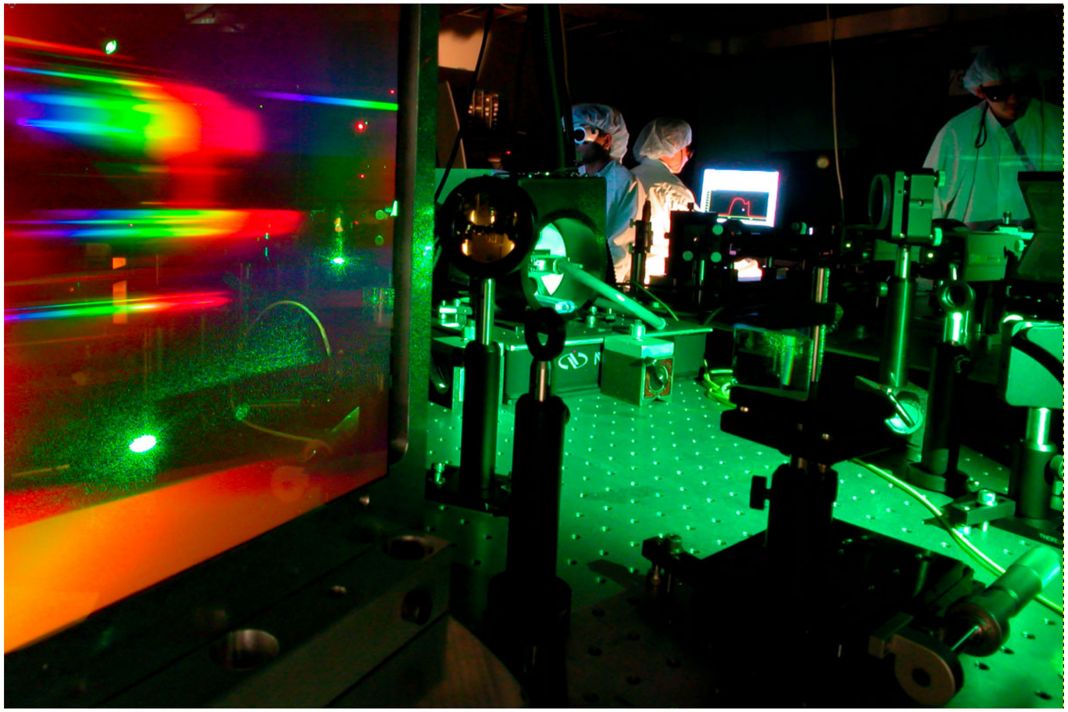
General Laser Safety Training



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Laser Safety Officer (LSO)

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Summary

- LLE Policy
- Lasers
- Potential laser hazards
- Laser classifications
- Control measures
- Engineering controls
- Administrative & procedural controls
- Administrative & procedural controls — Warning signs
- Personal protective equipment
- Best practices
- Instructions on satisfying laser-safety training requirements

Laser Policies and procedures are in accordance with:

- **ANSI Z136.1-2014** ***American National Standard for Safe Use of Lasers***

- **Occupational Safety and Health Administration (OSHA)**
  - This U.S. agency requires personnel to observe the ANSI recommendations for the safe use of lasers, and not following the ANSI recommendation can result in fines

- **U. S. Food and Drug Administration (FDA)**
  - The FDA is responsible for radiation-emitting product safety

    http://www.fda.gov/Radiation-EmittingProducts/RadiationEmittingProductsandProcedures/HomeBusinessandEntertainment/LaserProductsandInstruments/default.htm

- **New York State Department of Labor**
  - ***Part 50. LASERS***

    https://dol.ny.gov/system/files/documents/2021/03/cr50.pdf

- **University of Rochester**
  - ***Laser Safety Program for Research and Teaching Laboratories***

    http://www.safety.rochester.edu/labsafety/lasers/researchlasersprogram.html

Lasers and Intense Light Sources are regulated by LLE policy in Instruction 6200 (S-SA-M-064)

- No employee shall expose themselves or other employees to radiation energy that exceeds the Maximum Permissible Exposure (MPE) to eyes or skin as determined by ANSI Z136.1
- All employees shall wear Laser Protective Eyewear (LPE) as specified at the entrance to the laboratory
- All suspected exposures above the MPE* shall be reported to the Area Supervisor, the Laser Safety Officer, and the Chief Safety Officer
- Laser (or laser components) shall be introduced to the laboratory intentionally using the process detailed in Instruction 6200

*If you experience eye pain or visible skin irritation from working with a laser

Laser Safety Training will be commensurate with job responsibilities

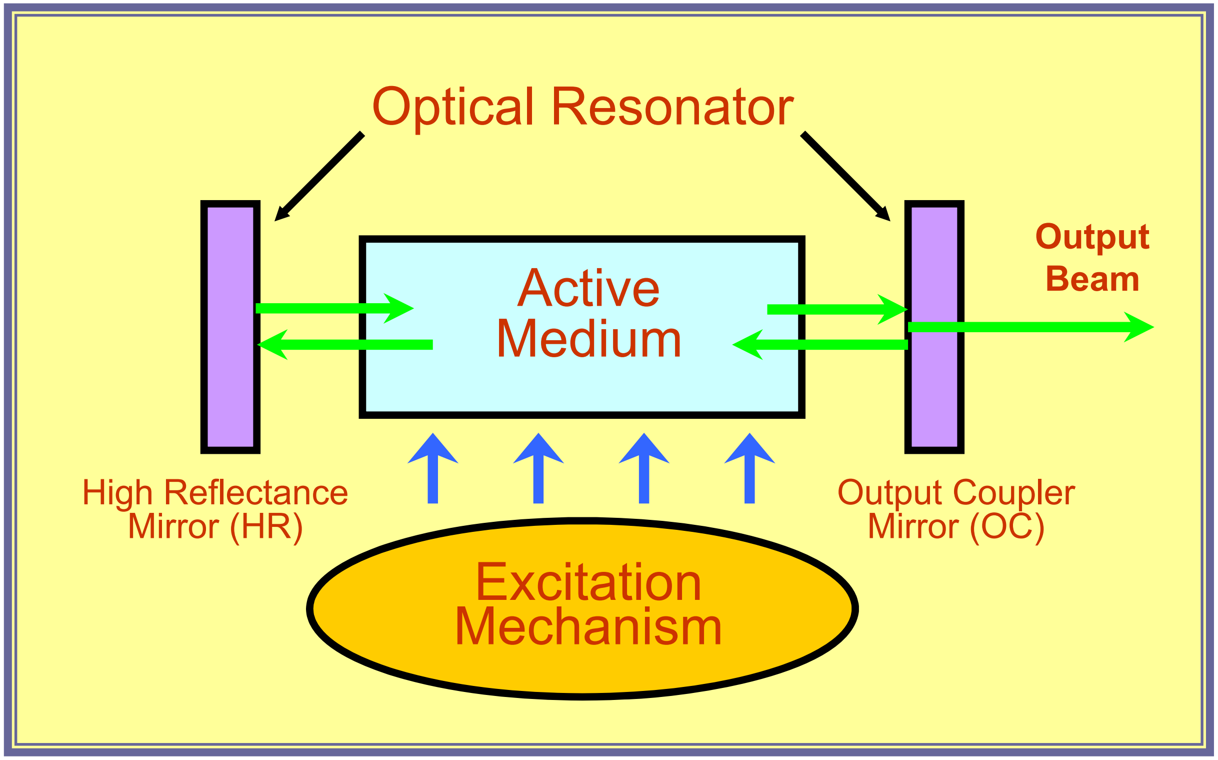
- All personnel who enter a laser environment with class 3B and 4 lasers shall complete General Laser Safety Training (this training) and require annual refresher training
- In addition to above, all personnel who will operate/maintain a laser or laser system shall complete a laser operator qualification card
  - Operation and maintenance must be performed per written and approved procedures
- Additional training (L_003: Laser Instrument Specialist Training) is required to integrate a new laser or modify an existing laser. This training shall be refreshed every three years.

This training is designed to educate workers who will enter laboratories where lasers may be present

You should know and understand the following:

1. The key characteristics of a laser
2. Types of hazards that can be presented by a laser beam and know that each laser presents unique hazards based upon it’s characteristics
3. Associated hardware can have non beam hazards.
4. Each laser will require specific protocol for safety and that the area supervisor will oversee training for specific job responsibilities
5. How to read laser hazard door signs and select appropriate Laser Protective Eyewear
6. This training does not allow you to operate, perform maintenance, or repair Class 3B or 4 laser systems. Further training is required in the form of a operator qualification card

Laser cavities have three basic components



Active medium: This can be a solid (crystal), semiconductor (diode), liquid (dye), or gas, which contains atoms that can emit light by stimulated emission. Also known as **lasing** or **gain medium**

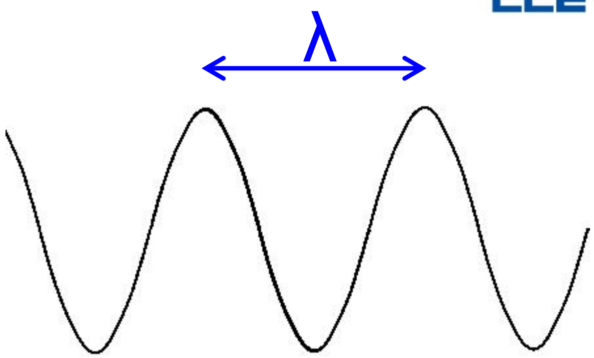
Excitation mechanism: this is the source of energy to excite the atoms to a proper energy state and can be optical, electrical, or chemical

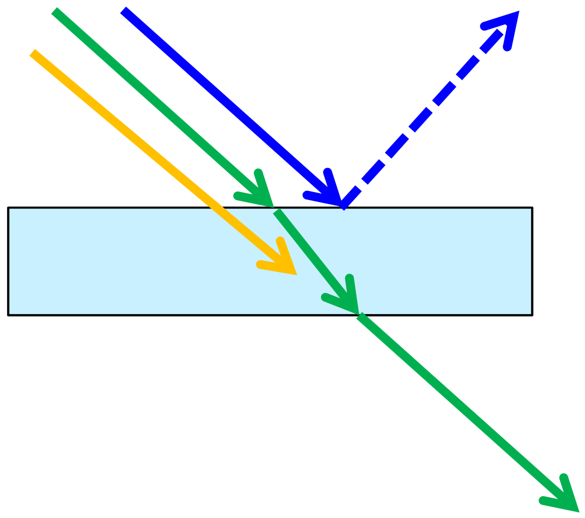
Optical resonator: this reflects the laser beam through the active medium for amplification and consists of a high-reflectance mirror and an output coupler mirror

*Courtesy, laser-professionals.com

Light Amplification by Stimulated Emission of Radiation

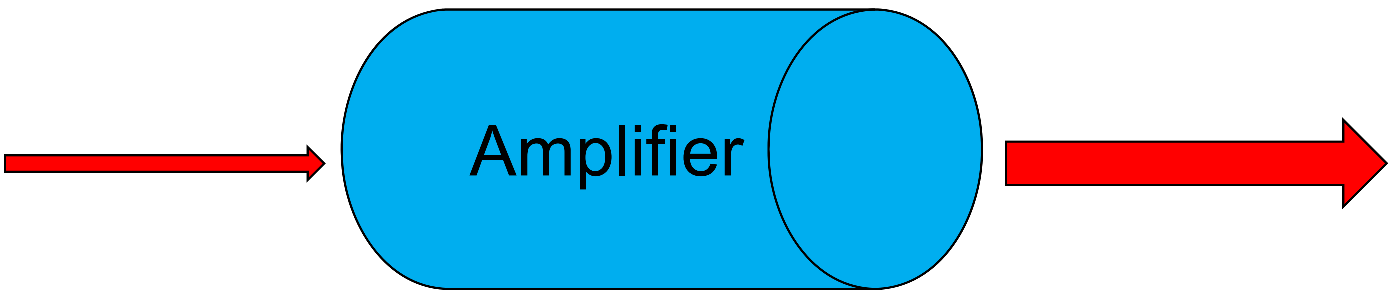
- LASER is an acronym
- Laser Light is characterized by the wavelength (λ) [and bandwidth (Δλ)]
- Light is
  - Reflected (e.g., mirror)
  - Refracted/transmitted (e.g., glass window)
  - Absorbed (e.g., sunglasses)
- Light absorption in a material can be characterized by the material's Optical Density (OD); OD is an important laser safety concept which is defined by the equation:
  - $OD = \log_{10}(1/T)$, where T=transmittance



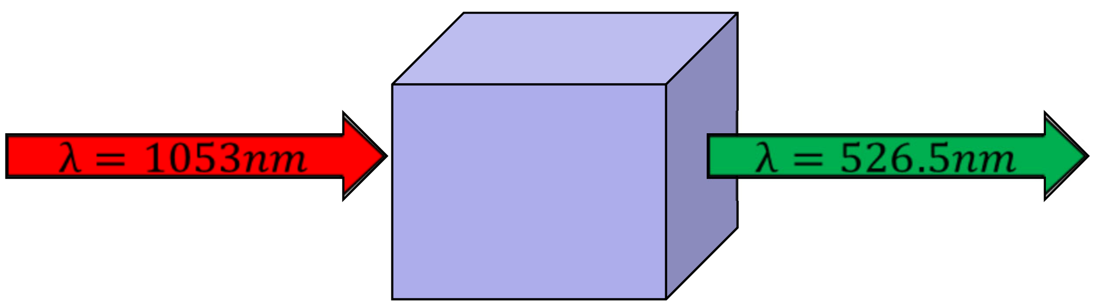


Subsystems that modify the laser beam are effectively a laser source.

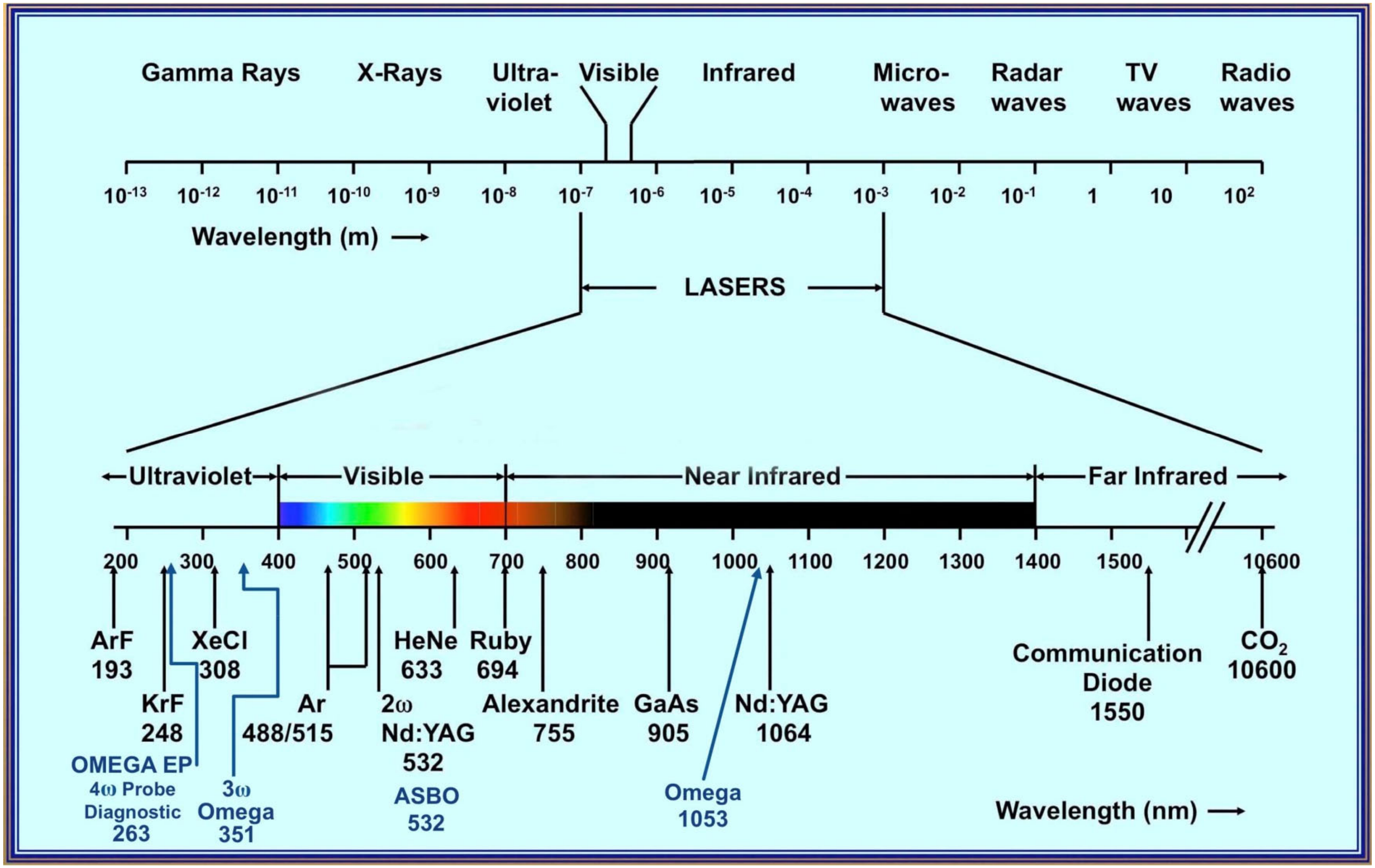
- **Amplifiers increase the energy or power of the beam.**



- **Frequency Conversion changes the wavelength of the beam**



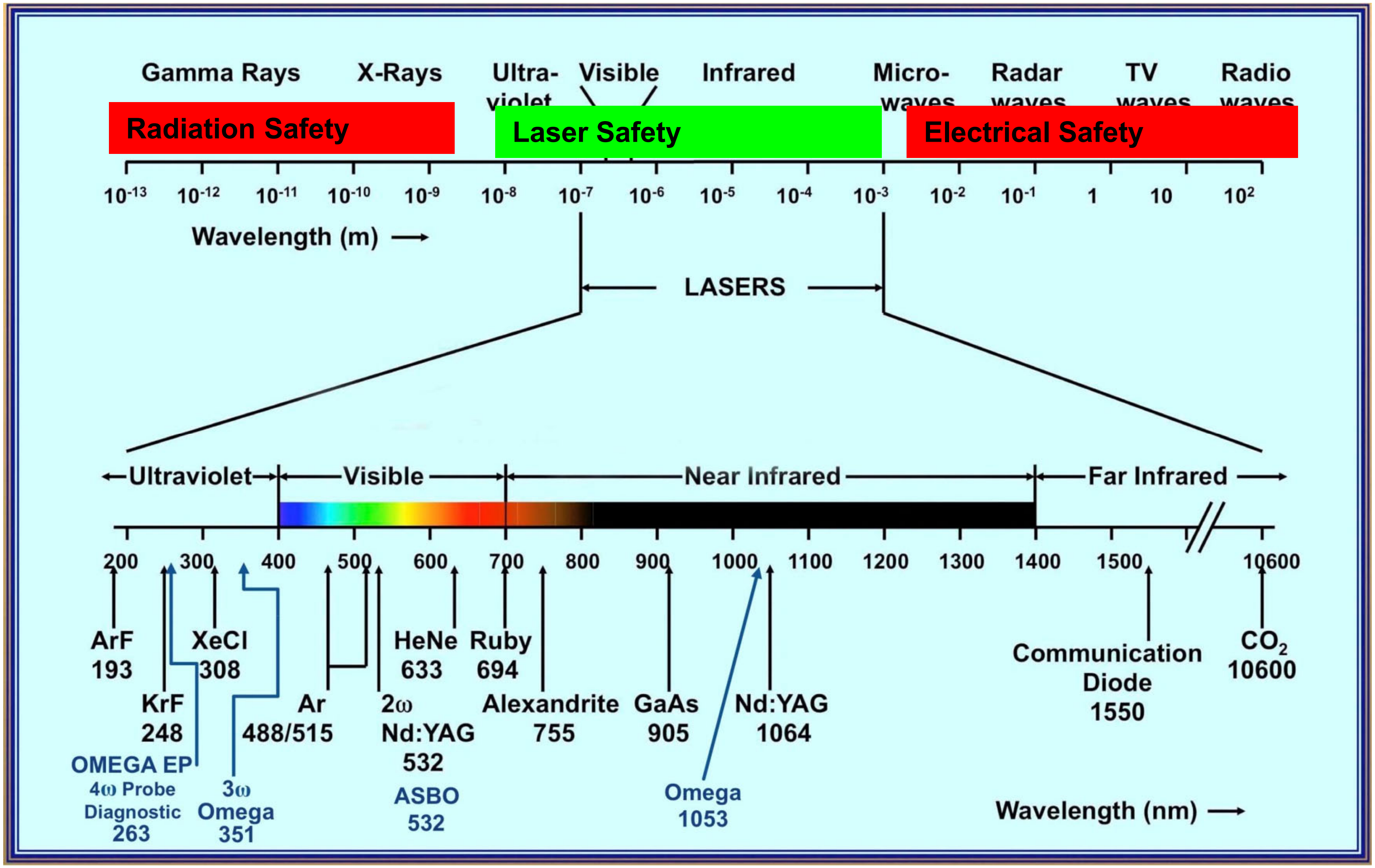
Common laser wavelengths are shown. On OMEGA, frequency conversion generate harmonics of 1053nm



ASBO = Active Shock BreakOut diagnostic @ LLE
Omega = Omega Laser Facility including OMEGA & OMEGA EP

Original, courtesy, laser-professionals.com

Wavelengths outside the Laser region are governed by other safety disciplines



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Original, courtesy, laser-professionals.com

At LLE, lasers are used for a wide variety of purposes

Uses include

- Fusion research
- Damage Testing
- Electro-optic Sampling
- Alignment
- Optical Quality Control
- Interferometry
- Spectroscopy
- Metrology
- Non-linear Optics
- Holography
- Index Measurement
- Reflectometry

All of these uses have the potential for exposing personnel to dangerous levels of laser radiation

Laser beams can cause serious eye and skin injuries

- Eye and skin injuries are the result of energy deposited and can be caused by:
  - Direct beam exposure
  - Specular (mirror) reflections (full or partial)
  - Diffuse (scattering) reflections

- High-power laser beams can burn exposed skin, ignite flammable materials, and heat materials to release hazardous fumes

- Many devices are used to modify the characteristics of the laser beam and can introduce additional laser hazards. These include
  - Amplifiers (increases energy of beam)
  - Frequency conversion (modifies the wavelength)

There are many potential hazards associated with lasers that are non-beam related

- Electrical hazards from power supplies, capacitors (even after the power is turned off), discharge lamps, ultraviolet (UV), visible, infrared (IR), microwaves
- Radiological hazards from X-ray or Gamma production
- Fire hazards from beam contact with flammable materials
- Chemical hazards
  - Components in the laser (e.g., laser dye)
  - Toxic fumes released from materials exposed to laser energy
- Component failures can be explosive (e.g., flash lamp)
- Noise levels can cause disorientation or hearing loss
- Mechanical components can create crush/pinch hazards

Many of these hazards are mitigated by interlocks. LLE Chief Safety Officer must give authorization prior to defeating any interlock

The Maximum Permissible Exposure (MPE) is used to determine hazard level and appropriate mitigation

- **Maximum Permissible Exposure (MPE)**: The level of laser radiation to which an unprotected person may be exposed without adverse biological changes in the eye or skin as defined by ANSI Z136.1

The MPE is a function of wavelength, pulse width and/or exposure duration. Think of the MPE as the damage threshold fluence for a person

Precautions must be taken to ensure that people are not exposed to hazardous levels of laser radiation. A dangerous exposure is to be investigated as an incident (in accordance with Instruction 6950)

No employee is to expose themselves or others to laser light above the MPE

Reported incidents, nationwide, have shown that

Accidents and injuries related to lasers are most often associated with the following, specific conditions:

1. Available eye protection not used!
2. Misaligned optics and upwardly directed beams
3. Unanticipated eye exposure during alignment
4. Equipment malfunction
5. Improper methods of handling high voltage
6. Unintentional exposure of unprotected personnel
7. Operators unfamiliar with laser equipment
8. Lack of protection for ancillary hazards
9. Improper restoration of equipment following service
10. Failure to follow standard operating procedures (SOPs)

Laser injuries often result from someone who should have known better but who took a short cut, producing an unnecessary, but very costly risk

Laser radiation damage mechanisms differ

UR LLE

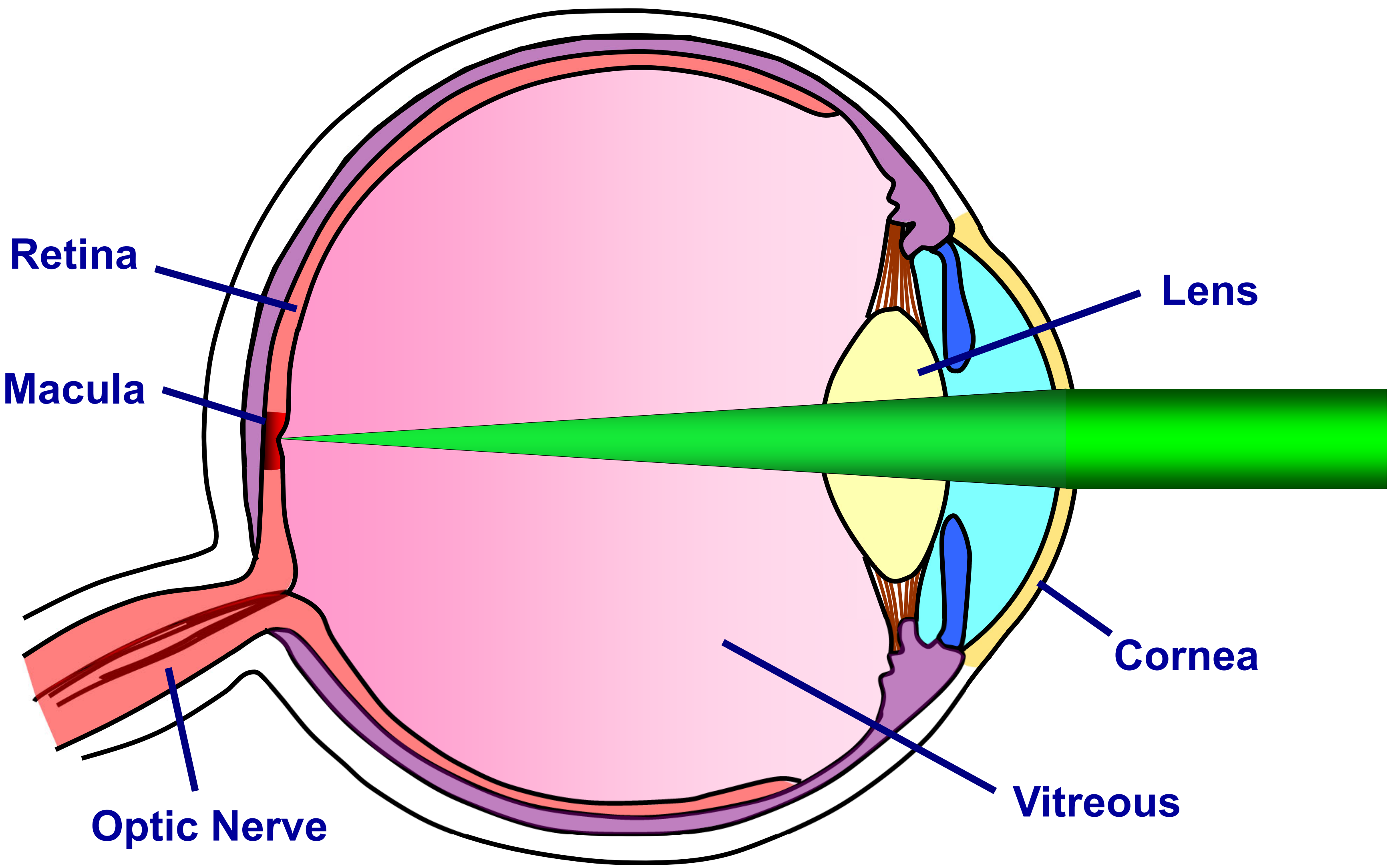
The principal cause of tissue damage is thermal in nature

- **Thermal effects are caused by a rise in temperature following absorption of laser energy**
- **Blast damage can result when temperature rises rapidly (especially with water vaporization)**

Photochemical effects result when laser radiation breaks chemical bonds

- **Continuous wave (CW) lasers: as defined by the ANSI standard are lasers that have a continuous output longer than ¼ second. CW lasers primarily cause thermal and photochemical effects**
- **Pulsed lasers: as defined by the ANSI standard are lasers that have a single or pulsed output shorter than ¼ second. Pulsed lasers additionally can cause Blast Damage**

Anatomy of the human eye*



*Courtesy, laser-professionals.com

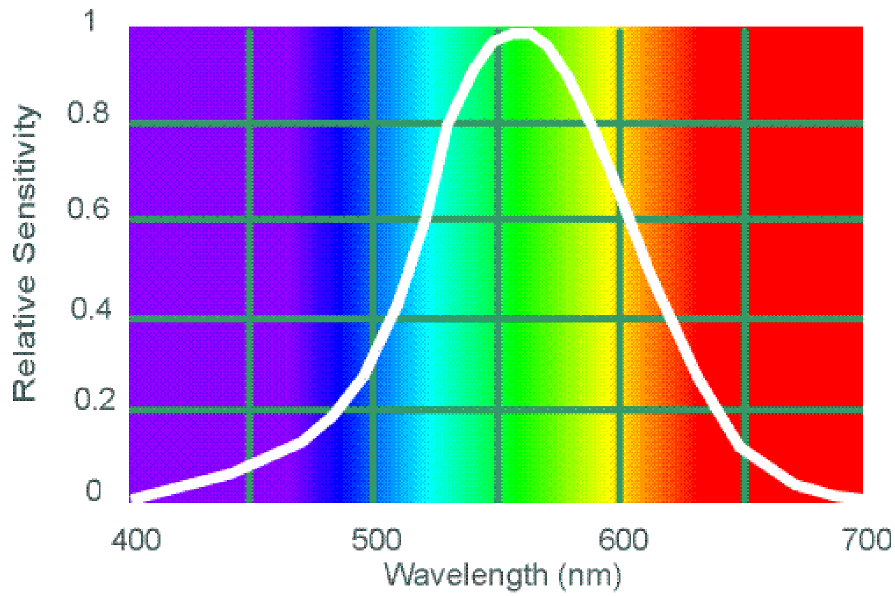
Laser wavelength determines where the energy is deposited in the eye

- **Ultraviolet (UV) 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 (400-700 nm) and infrared (IR) radiation (700-1400 nm) can damage the retina**
- **Far Infrared (IR) radiation (1200-1400 nm) can damage the cornea. Longer wavelengths damage the lens**

The eye is designed to intensify (focus) light making eye exposure the principal hazard associated with laser radiation

The sensitivity of your eye to laser light is not constant over the visible spectrum

- **Hazard is approximately constant for laser light from 400-700nm**
- **Visual sensitivity is not constant over this same range. This explains why green (~532nm) lasers appear bright when equal intensity red (650nm) or blue (400nm) lasers appear dim**
- **Do not equate perceived brightness with hazard level especially as you get further out in the wings of your eye's sensitivity. i.e lasers that appear dim can damage your eye**

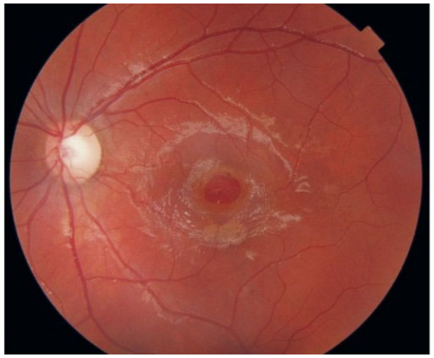


Visual sensitivity at wavelength peaks in the green portion of the spectrum, but hazards are nearly equal across the visible range

Your large skin surface makes accidental exposures common

- UV, visible, and IR exposure can cause pigment darkening, photosensitive reactions, & skin burn
- Chronic exposure to UV wavelengths (200-400 nm) can have a carcinogenic effect
- Reducing the surface area of exposed skin decreases the risk of accidental exposure to laser radiation
- Pay particular attention to your hands while doing work around the laser beam

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



Top images depict laser damage caused by a laser pointer

Laser pointers should be designed with energy below the MPE, but users can overcome their reflexes to stare into the beam too long

Poorly designed/manufactured laser pointers may emit a laser beam that exceed the MPE

Lasers present a real hazard. Diligent use of safe operating practices and Laser Protective Eyewear (LPE) prevents injury

Lasers are classified according to their hazards

Laser Class	Hazard Level
1	Incapable of causing injury during normal operation
1M	Incapable of causing injury unless optical system is used to collect light
2	Visible light laser incapable of causing injury in 0.25 seconds
2M	Visible light laser incapable of causing injury in 0.25 seconds unless optical system is used to collect light
3R	Safe when handled carefully. Can cause flash blindness and disorientation. **Extended viewing could cause damage. Less than 5 mW of visible light (400-700nm)**
3B	Can cause eye injury
4	Can cause eye injury. Can cause skin injury or ignite a fire

Lasers are classified according to their hazards

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1M	Incapable of causing injury unless optical system is used to collect light
3B	Can cause eye injury
4	Can cause eye injury. Can cause skin injury or ignite a fire

Knowing the laser class allows you to know the relative hazards of a laser.

- Class 3B and 4 can cause eye or skin injury
- Other classes will not cause eye or skin injury when used according to manufacturer's instructions

Before use, know the laser class and act accordingly

- **Laser Class is determined by the entire device (including engineering controls)**
  - **A DVD player is labeled as Class 1, but has a Class 3B or 4 laser inside (Do not open the case!)**
- **Class 1, 1M, 2, 2M, and 3R systems are to be used carefully in accordance with manufacturers guidelines. *Additional protocol is not required***
  - **These lasers are not to be modified without the express consent of the Laser Safety Officer (and it will not be granted without a design review process)**
- **When using lasers, if you experience discomfort, *STOP!* and consult with the Laser Safety Officer.**

At LLE, a Class 3R laser was found to output higher energy when in proximity with a radio transmitter. No injuries were sustained thanks largely to the engineer recognizing a problem and stopping work (Incident Report 265)

A standard mitigation strategy will be applied in the design process for laser systems

1. Selection: Select a Laser for use which has enough, but not excessive, energy. Procure an alignment laser (or laser with low power mode)
   – Elimination: remove unnecessary laser hardware
2. Engineering Controls: Design features that prevent hazard exposure including enclosures, interlocks, beam dumps, etc
3. Administrative Controls: All measures that inform the user how to behave safely including training, warning signs, procedures, reference material, incident investigation records, etc
4. Personal Protective Equipment: Laser Protective Eyewear, gloves, lab coat that prevents exposure when other controls have failed

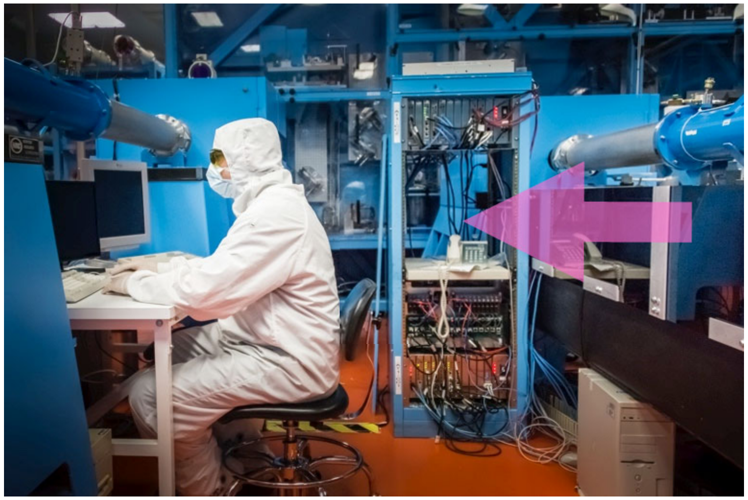
Each laser must be evaluated to determine the hazard involved and the required safety measures

Good Engineering controls start in design, but must be maintained through operation

- **Door sign interlocks are required for Class 3B and 4 lasers.**
- **An enclosure can be used to prevent beam hazards.** ***In some cases, the enclosure is used to change the hazard class***
  - ***Enclosure can be interlocked to prevent laser propagation when panels are removed. <u>Do not defeat interlocks without the approval of the Chief Safety Officer</u>***
  - ***Viewing ports with appropriate attenuation to provide protection***
  - ***Remote controls so that enclosure does not need to be violated***
- **Avoid designs at eye level for standing/seated individual**
  - **Work stations should be protected by a barrier**
- **Terminate beams intentionally into beam dumps designed to handle the thermal load of the laser**
  - **Including partial reflections or mirror leakage from optics in beam path**
- **Type 3B and 4 laser are required to have key control**

Know the engineering controls and <u>do not</u> defeat them

An example of engineering controls addressing the safety of the computer user in a laser environment



Any location where stray laser light could shine towards workers sitting at a computer requires barrier protection

Optical Fiber Laser Systems are treated as a special case for engineering controls

- **Laser transmission systems which employ optical fibers shall be considered enclosed systems with the optical fibers forming part of the enclosure.**
- **If disconnection of a connector results in radiation emission below the applicable MPE, then connection or disconnection may take place in an uncontrolled area and no other control measures are required**
- **If greater than above the applicable MPE via a connector, then the following will take place:**
  - **Deactivate the laser before making or breaking fiber connections**
  - **Label devices and connectors where hazardous emissions can occur**
  - **Label fibers carefully so that you are working on the right hardware (rather than for a source that is not disabled)**
    - **Lockout/Tagout must be applied at the laser source before breaking class 3B or Class 4 fiber connections. Verify (again) when connection is broken**

Administrative and procedural controls supplement engineering controls and PPE

These controls include

- **Laboratory Instructions, directives, and operating procedures**
  - **Including best practices while building or modifying laser systems**
- **Safety training orientations and annual refreshers**
- **On-the-job training & laser operator qualification ("Qual Card")**
- **"Buddy System"**
- **Laser safety signs**
- **Laser inventory and Laser Activation Checklists**
- **Web-based resources**
- **Safety inspections (periodic, new installations, or following modifications, or following an inquiry)**

Laser Protective Eyewear (LPE) is required to enter a laboratory where a Class 3B or 4 laser is in use

- Laser Eyewear can prevent injury when other controls fail
- LPE is characterized by wavelength of protection and OD of protection at that wavelength
  - No single LPE provides protection for all possible lasers. LPE requirements are based upon the laser characteristics.
  - The color of the lens is not adequate for determining protection
- The LSO will calculate the required OD during acquisition of a laser. This OD will be on the door sign.
- Users must verify that the OD on the eyewear exceeds the OD on the door for adequate protection

Warning signs address different environments

Although accident prevention signs are classified by ANSI Z535.2, the laser 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, "DANGER"
- **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, & Class 3R that do not exceed the applicable MPE

Custom warning signs are made for each laboratory to address specific hazards

- Many labs are equipped with illuminated style signs
  - Warning does not apply unless illuminated sign is flashing
  - Rooms are being fitted with interlock circuits so that warning signs are activated to enable the laser. This will take time to implement everywhere
- Signs that are printed are applicable whenever they are visible
- Before activating a laser, verify the sign is active and other personnel in room are notified

Laser Safety Signs and LPE refer to the OD. Let's review OD

- **Optical Density*** (**OD**) characterizes the fraction of light blocked (absorbed) by laser protective eyewear
  - When OD=1 at a wavelength, 90% of the incoming light *at that wavelength* is blocked. 1/10th of the light transmits
  - When OD=5 at some wavelength, 99.999% of the incoming light *at that wavelength* is blocked. 1/100000th of the light transmits

- Make sure that the OD listed on the eyewear is ***equal to or greater than*** the OD required *for every wavelength listed on the sign*
  - The OD can be specified for a single wavelength or a range of wavelengths

*OD = $\log_{10}(1/T)$, where T=transmittance

A higher OD value means the eyewear will provide greater protection at the specified wavelength(s)

Eye Protection Guidelines

- Verify proper OD protection for the wavelengths on the laser sign
- Put on laser protective eyewear before entering a laser hazard area
- Although our eyewear is designed to protect us, never look directly into the laser beam. Not all eyewear can sustain protection for full beam energy
- Wear eyewear to current prescription
- The color and/or darkness of your laser protective eyewear's lens does not unambiguously indicate the protection the lens provides, either in wavelength or optical density
  - e.g., eyewear with green tinted "lenses" will not protect you from green laser light

Care and maintenance of protective eyewear

- Check and clean the eyewear before every use
- Appropriate cleaners are provided; if you use a towelette, blow off any dust or dirt to avoid scratching the lens
- Immediately remove eyewear from service when lenses or frames are cracked, broken or significantly scratched. Return it to the Laser Safety Officer for disposal
- Laser protective eyewear that is provided in specific areas or for specific tasks must NOT be removed from that area (other labs generally have different requirements)
- Contact your supervisor to obtain replacement prescription safety eyewear, or the work area supervisor for non-prescription safety eyewear
- Store safety eyewear in a protective case or in designated storage locations when not in use

How to obtain prescription lenses for laser protective eyewear

LLE will reimburse you for prescription eyewear inserts

1. **One vendor of laser protective eyewear with the prescription insert is the Honeywell Sperian XC series frames**
   - **These inserts (prescription lens holder) may be obtained from the Omega Facility Administrative Assistant**

2. **Take the insert to your eyewear vendor of choice, and pay for it**

3. **For reimbursement, take the receipt to your division's designee**

Laser protective eyewear comfort and fit are important during your selection

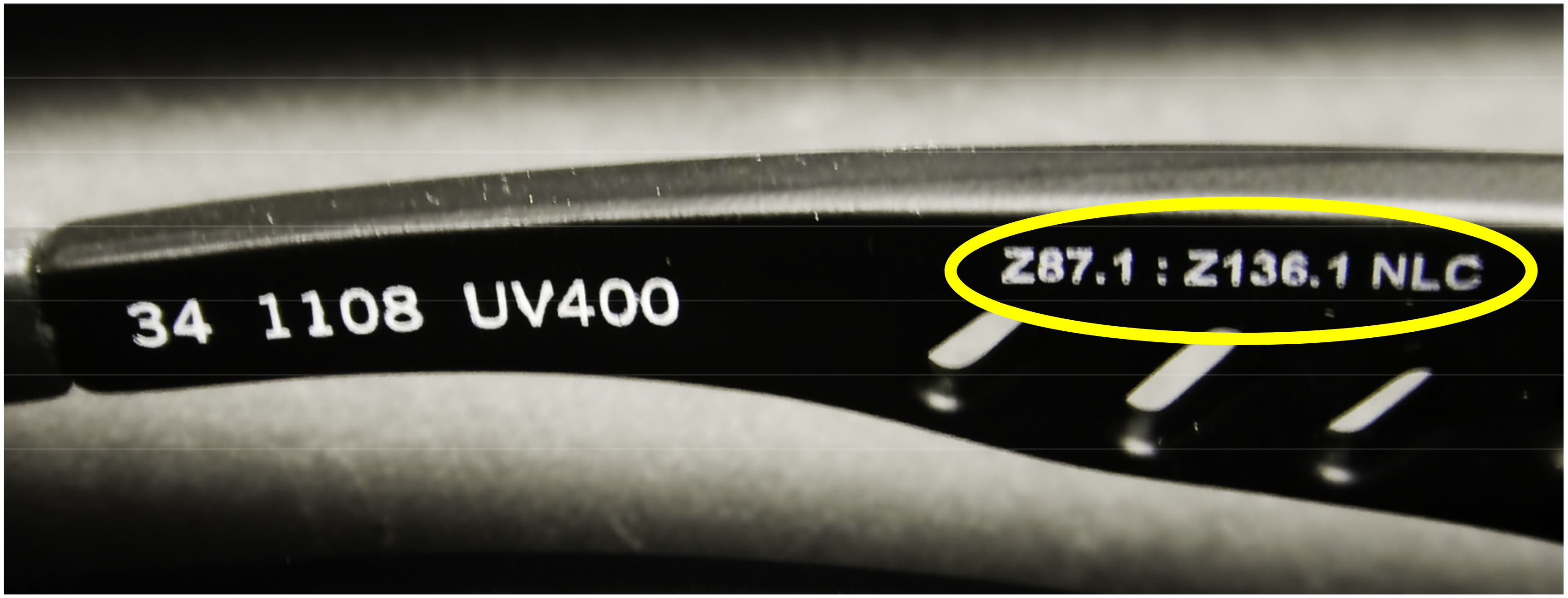
- Eyewear must fit to provide good protection
  - Gaps around the edges of the frames are locations with no laser protection
- Turn your head toward the object you want to see (do not look around your laser protective eyewear)
- Do not look around the eyewear for reading or computer work. If you can't see for functional tasks, talk to the work area supervisor and LSO for better options (increase lighting, better computer monitor, or better suited LPE)
- Safety eyewear having an elastic headband are easily adjustable for a secure fit (even in precarious situations)
  - Safety eyewear employing headbands should have the breakaway feature if used in an environment where a strangulation hazard is possible (i.e., wearing laser eyewear with a headband while operating a drill)

Eyewear retainers should be properly secured

Retainers are available from the laser safety officer

All LLE laser protective eyewear must comply with two ANSI standards

- **ANSI standard for laser safety, Z136.1, and**
- **ANSI standard for mechanical impact resistance, Z87.1**

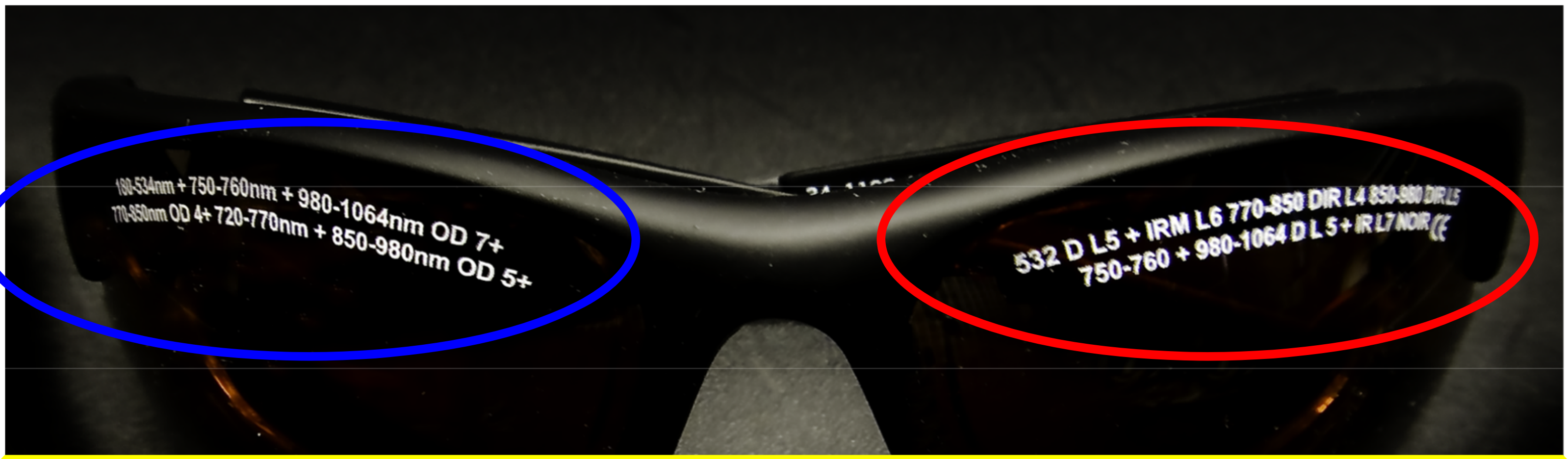


This eyewear is labeled with the wavelengths for which they offer appropriate protection

There are two labeling standards used on protective laser eyewear:

- **American National Standards Institute (ANSI)-- Wavelengths and OD**
- **European and labeled with "CE" is not equivalent and should not be used to determine if the eyewear is appropriate at LLE**

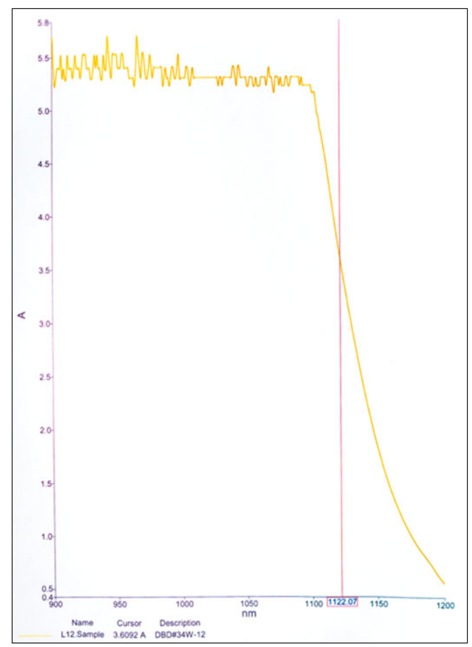
If you have a question on the labels, please ask your supervisor or contact the laser-safety officer



All LLE signs use the ANSI standard with wavelength called out in nanometers (nm)

Eyewear identified with LLE added labels

- If it is necessary to use laser safety eyewear at wavelengths other than those listed on the lens by the manufacturer, contact the Laser Safety Officer or Chief Safety Officer BEFORE putting them into service. They MUST be measured and labeled by the safety office
- The laser safety e-log has a section documenting these filters



When eyewear becomes foggy

- **Never remove LPE while in the laser environment**
  - Eye lids do not provide adequate protection from a laser beam
  - Walk out of the laser environment if you must remove LPE
- Do not let the LPE slip down to the end of your nose for ventilation
- Some tips for reducing the fogging effect
  - Clean lenses with defogging tissue
    - *Fogtech DX* works pretty well
  - Ensure your face mask is well positioned and breathe through it
  - Cleanroom tape across the bridge of your nose can significantly reduce fogging (but can be uncomfortable to wear and remove)
  - Pace yourself

Eyewear storage units can have multiple types of eyewear with different protections

Remember to return safety eyewear to their original location!

It may or may not be appropriate for other labs

Fluorescence — an eyewear response when struck by a laser beam

- Fluorescence is the re-emission ("glow") of absorbed (laser) light. Some materials used for laser protective eyewear exhibit fluorescence following exposure to laser light.
- Fluorescence is frequently at a different wavelength (color) than the (laser) source
- Eyewear fluorescence can startle the wearer, and cause the wearer to question its effectiveness
- If eyewear fluorescence is observed, it indicates unmanaged/stray laser beams are present that must be eliminated
- Individuals who observe eyewear fluorescence shall bring it to the attention of the work area supervisor and Laser Safety Officer
  - <u>Eliminate the beam that caused the fluorescence!</u>

Laser protective eyewear deficiencies are cited in many incidents where injury occurs

- Around the Nation:
  - An undergraduate student was working at a national laboratory with a Class 4 laser to suspend particles. Neither the student nor the supervising scientist were wearing laser protective eyewear
  - As the student bent down to look into the chamber, she saw a flash and immediately noted a reddish brown substance floating in her left eye. The student had irreversible eye damage—a retinal traumatic hole caused by pulsed laser light.
- Here at LLE:
  - Incident Report 153. An operator was working in the lab wearing LPE. While leaning over the optical table and leaning head into a known laser beam path, the operator saw a flash and recognized a spot in vision. The employee had irreversible eye damage. Investigation concluded that gaps in the fit of the eyewear caused the beam to bypass the protection.

Before you can use a Class 3B or 4 laser, additional training is required

- **Completion of a Laser Operator Qualification Card is required**
  - **Training sessions will be with the Work Area Supervisor, Laser Instrument Specialist, other Operators, and the Laser Safety Officer**
- **A Laser Operator is permitted to follow written procedures to operate the system**
- **A Laser Operator is <u>not</u> permitted to modify the laser system or perform repairs to the system**

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 ❑ Electrical Safety (or ❑N/A)
❑ Laser Safety Training ❑ Chemical 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. Locate startup, shutdown, operations, and maintenance procedures	______ / ______ Laser Instrument Specialist
7. What should you do if you have a concern about the operation of this laser	______ / ______ Laser Instrument Specialist
8. Who is permitted to provide corrective service to 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

New laser equipment must be reviewed before use in the laboratory

- Laser Instrument Specialist (L_003) training is required to introduce a new class 3B or 4 laser at LLE.
  - Laser Instrument Specialist is responsible for oversight of laser operation
  - Laser Instrument Specialist responsibilities will be transferred as required over the lifetime of the laser
- A LLE designed laser must go through the Instruction 7700 process
  - Safety will be a key point for discussion at design reviews
- When you are purchasing a new laser, talk to the LSO and fill out a Laser Inventory Form (S-SA-M-066)
- When the laser arrives, the laser instrument specialist & LSO must verify that laser specifications and that safety measures are in place before activating. The checklist for this is (S-SA-M-067)

See the LSO early and whenever system changes occur to ensure that the safety protocol is in place when the laser arrives

Follow these best practices, and call out your colleagues if they violate these guidelines

1. **Securely mount the laser on a stable platform to maintain the beam in a fixed position during operation at a beam height much lower than head height. Be wary to avoid bringing your head down to the beam height**
2. **Do not send a hazardous beam into a walkway or any space where someone might place their head. If necessary to do so, a beam tube or chains is required to ensure people are aware**
3. **Minimize transient reflections: remove watches & jewelry, and be careful with tools. Install optics carefully at minimum beam energy**
4. **Terminate all beams intentionally. Investigate for stray beams regularly during work especially after installing a new optic**
5. **Use cameras to detect alignment. Avoid staring at alignment cards or targets when possible as they are diffuse reflectors capable of causing eye damage over long periods of time**

More about beams in walkways

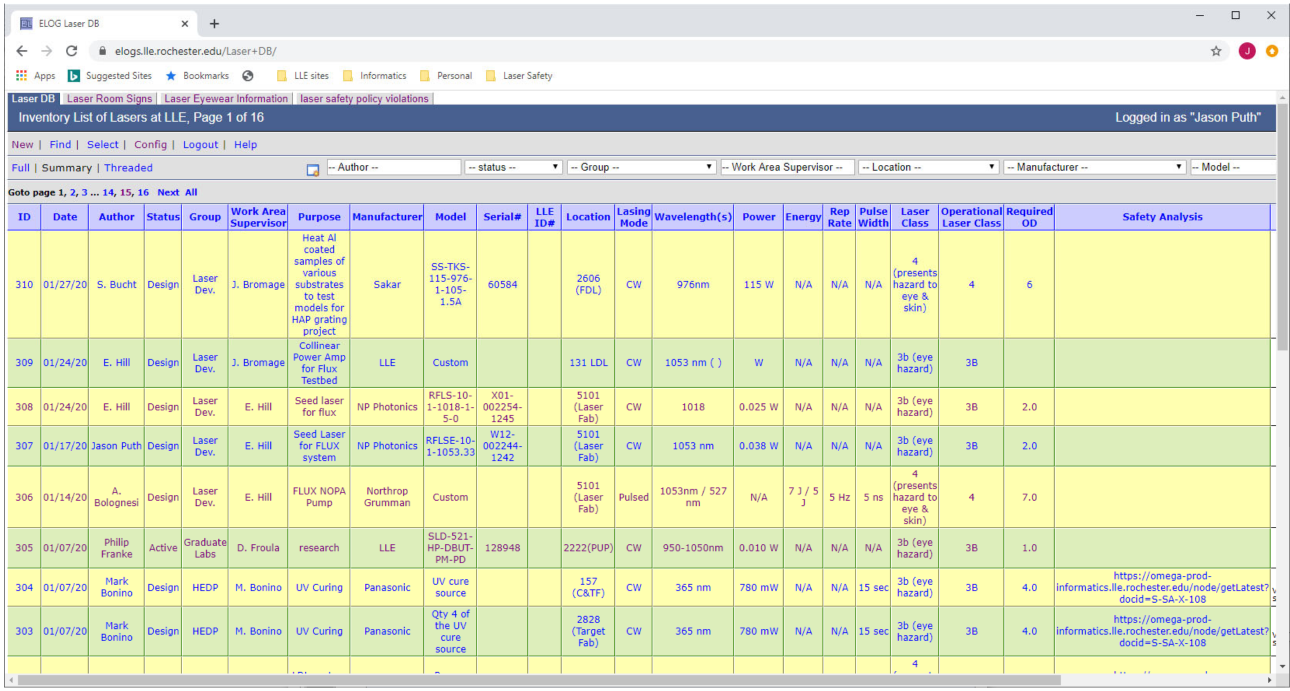
- If a beam exceeds the MPE for the eye, use a beam tube or chains to remind workers that a hazard exists
- If you are trained to access the area, then removing the tube or chains is permissible, but must be restored as soon as you pass through
- Do not linger in the beam path
- If you need to do work that will place you in the beam path, lock out the laser source before beginning the work
- There are exceptions where tubes would cause a trip hazard or where access is strictly controlled and training keeps workers cognizant of the beam

Laser Information is tracked on a webpage

- **The Laser Instrument Specialist is designated the Author and is responsible for keeping inventory up to date when system changes/moves**
- **Work Area Supervisor will participate in safety tour where the inventory is audited**
- **Notify Laser Safety Officer when changes are required**
- **<u>Procedures can be attached for easy reference</u>**

https://elogs.lle.rochester.edu/Laser+DB/

Note that first time users must **"Register as a new user"** at the login prompt



ID	Date	Author	Status	Group	Work Area Supervisor	Purpose	Manufacturer	Model	Serial#	LLE ID#	Location	Lasing Mode	Wavelength(s)	Power	Energy	Rep Rate	Pulse Width	Laser Class	Operational Laser Class	Required OD	Safety Analysis
310	01/27/20	S. Bucht	Design	Laser Dev.	J. Bromage	Heat Al coated samples of various substrates to test models for HAP grating project	Sakar	SS-TKS-115-976-1-105-1.5A	60584		2606 (FDL)	CW	976nm	115 W	N/A	N/A	N/A	4 (presents hazard to eye & skin)	4	6	
309	01/24/20	E. Hill	Design	Laser Dev.	J. Bromage	Collinear Power Amp for Flux Testbed	LLE	Custom			131 LDL	CW	1053 nm ( )	W	N/A	N/A	N/A	3b (eye hazard)	3B		
308	01/24/20	E. Hill	Design	Laser Dev.	E. Hill	Seed laser for flux	NP Photonics	RFLS-10-1-1018-1-5-0	X01-002254-1245		5101 (Laser Fab)	CW	1018	0.025 W	N/A	N/A	N/A	3b (eye hazard)	3B	2.0	
307	01/17/20	Jason Puth	Design	Laser Dev.	E. Hill	Seed Laser for FLUX system	NP Photonics	RFLSE-10-1-1053.33	W12-002244-1242		5101 (Laser Fab)	CW	1053 nm	0.038 W	N/A	N/A	N/A	3b (eye hazard)	3B	2.0	
306	01/14/20	A. Bolognesi	Design	Laser Dev.	E. Hill	FLUX NOPA Pump	Northrop Grumman	Custom			5101 (Laser Fab)	Pulsed	1053nm / 527 nm	N/A	7 J / 5 J	5 Hz	5 ns	4 (presents hazard to eye & skin)	4	7.0	
305	01/07/20	Philip Franke	Active	Graduate Labs	D. Froula	research	LLE	SLD-521-HP-DBUT-PM-PD	128948		2222(PUP)	CW	950-1050nm	0.010 W	N/A	N/A	N/A	3b (eye hazard)	3B	1.0	
304	01/07/20	Mark Bonino	Design	HEDP	M. Bonino	UV Curing	Panasonic	UV cure source			157 (C&TF)	CW	365 nm	780 mW	N/A	N/A	15 sec	3b (eye hazard)	3B	4.0	https://omega-prod-informatics.lle.rochester.edu/node/getLatest?docid=S-SA-X-108
303	01/07/20	Mark Bonino	Design	HEDP	M. Bonino	UV Curing	Panasonic	Qty 4 of the UV cure source			2828 (Target Fab)	CW	365 nm	780 mW	N/A	N/A	15 sec	3b (eye hazard)	3B	4.0	https://omega-prod-informatics.lle.rochester.edu/node/getLatest?docid=S-SA-X-108

EASY HAZ™ is available so that you can verify the LSO calculations

EASY HAZ™ Basic Web Version. **Their laser hazard analysis software is free and online at**

http://lasersafetyu.kentek.com/easy-haz-laser-hazard-software-basic-web-version/

- **It provides minimal hazard calculations; see restrictions online**

Software has limitations and can behave strangely to incorrect input. If you have questions, contact the Laser Safety Officer

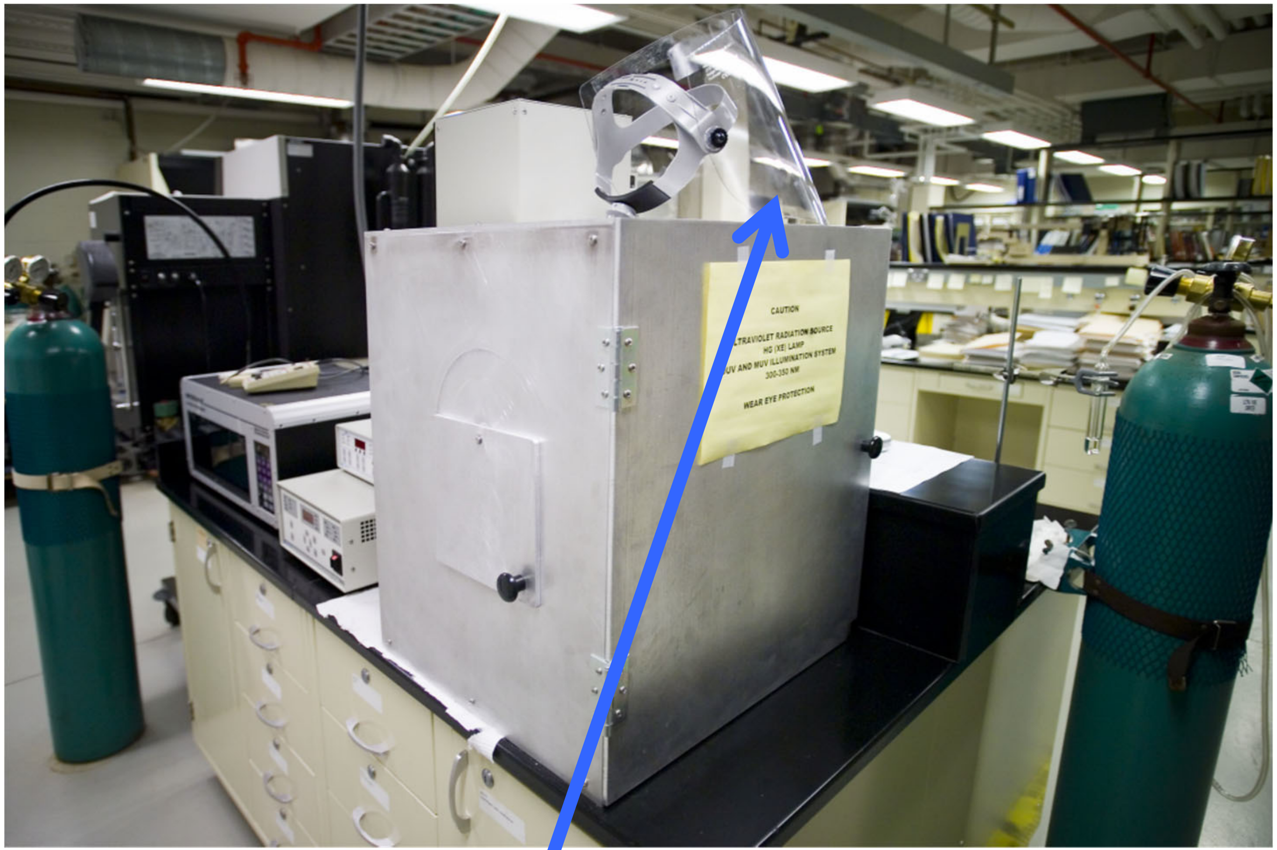
The response to a suspected exposure to laser radiation is well defined

- Stop work!!
  - If available use the red dump button to safe lasers and other hazards. If not available, leave the lab
- Get help
  - Eye injuries may cause significant disorientation and difficulty. Obtain help from people around you or call LLE receptionist (55101) and state "Medical Emergency"
  - Do not drive until you have had medical attention
- Get qualified medical attention
  - The individual with a suspected eye injury shall go to the Flaum Eye Institute Patient Care (585-273-3937, ask for Dr. David Maxwell Kleinman MD) or personal ophthalmologist
  - The individual with a suspected skin injury shall see a physician
- Inform management
  - Work Area Supervisor, Supervisor, Laser Safety Officer, Chief Safety Officer, and Administrative Division

Non-laser, intense sources can also be potential hazards

- Caution signs shall be prominently displayed
- If necessary, customized enclosures should be constructed
- If in doubt, the manufacturer's eyewear should be tested for proper protection
- UV lamps are a common example

Custom-built UV enclosure



Notice: **full-face protection used at this installation**

Potential retinal hazards from blue light-emitting diodes (LED)

Harmful effects. Severe headaches and nausea caused by blue light triggering the eye muscles to shut down. Intense blue light is also capable of causing permanent photochemical damage to the eye.

- **The intensity of the blue light is often undetected because the sensitivity of the human eye is very low at 400 nm**
- **Normally, the viewer would blink or look away from an intense light source**
- **However, an intense blue light source is especially dangerous because it does not appear to be bright and a viewer's natural reaction to look away does not provide protection from long-term exposure**
- **The viewer may look at such a source for many seconds or minutes without their blink response ever kicking in**
- **Also known as high-energy visible light, 380-530 nm, and specifically a blue-light hazard, 400-500 nm**

Laser pointers can be dangerous

- The safest laser pointers are those which do not exceed 1 mW output (Class 2)
- The FDA has issued warnings about the possibility of eye damage to children from hand-held pointers and has indicated that the light energy from a laser pointer aimed into the eye can be more damaging than staring directly into the sun
- The FDA and ANSI Z136.1-2014 restrict a laser pointer's emission limit to 5 mW in the visible spectrum (Class 3R); 2 mW in the infrared. Class 3R must not be pointed at a person's eye
- Recent tests by the National Institute of Standards and Technology (NIST) show that 90% of green pointers and 44% of red pointers tested were out of compliance with federal safety regulations*
  – Green laser pointers frequency-convert infrared laser light. Poorly designed devices may emit both green and potentially injurious invisible IR light

*www.nist.gov/pml/div686/pointer-032013.cfm

Injuries & consequences associated with laser pointers

- **Eye doctors at Iceland's Landspitali University Hospital treated a 13-year-old boy who was seriously injured in both eyes after playing with a 90-milliwatt laser pointer purchased outside the country. He was said to have lost central vision in one eye.***
- **Medical helicopter pilot blinded by a laser and has to make emergency landing; an arrest was made**
- **From the FBI: "*If you point a laser and interfere with the operation of an aircraft, that's a felony. The crime carries a maximum of 20 years in federal prison and a quarter of a million dollars fine. In addition, the FAA can impose a civil penalty of up to $11,000 for each violation.*" ****

**http://www.laserpointersafety.com/news/news/nonaviation-incidents_files/383588a2c761851796992941a921673c-300.php#on*

***http://www.fbi.gov/news/videos/making-a-point-about-lasers*

FDA recommends that consumers be cautious when buying laser products over the internet*

- Consumers may unknowingly purchase an illegal laser product or may lose their money if the illegal product is refused entry into the U.S.
- The brightness of a laser beam does not always indicate its relative power or potential for injury in comparison to other color laser beams. Powerful blue or violet lasers will appear less bright in comparison to equally powerful red laser beams and much less bright in comparison to equally powerful green laser beams
- A blue or violet laser beam that appears as bright as a red or green laser is very likely to be a powerful laser that can cause immediate eye damage. Blinking or looking away when exposed directly to the beam may not provide sufficient protection to avoid injury to the eye

*http://www.fda.gov/Radiation-EmittingProducts/RadiationSafety/AlertsandNotices/ucm116534.htm

High Intensity flashlights can cause eye injury

- While at home doing personal work, an LLE employee used a bright flashlight to inspect a computer.
- Reflective surfaces on the computer chassis reflected the beam into the individual's face resulting in eye damage
- Doctors at the local specialist office (Flaum Eye Institute) indicate that the injuries should heal because the employee averted eyes quickly enough to avoid more serious damage

Pain when using a light source is indicative of nearing the damage threshold. Don't ignore the pain; stop work! Safety Officers are here to help

Avoid ultra bright lights for casual use. Limit to specific tasks and be conscientious about where the light is going

Instructions on satisfying the laser-safety training requirements

1. **Visit the LLE Safety Zone "*Training*" tab**
   http://safety.lle.rochester.edu/520_training/presentations.php

2. **Read the L_001 Laser Safety Training presentation and Instruction 6200**

3. **Complete and submit the L_001 quiz**

- **New employees/students – after receiving your graded quiz, contact the LSO for an orientation session (~30min)**

- **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**