LA-UR-11-10559
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Title:	Practical laser safety for university labs
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Intended for:	seminar

Practical laser safety in a university lab setting

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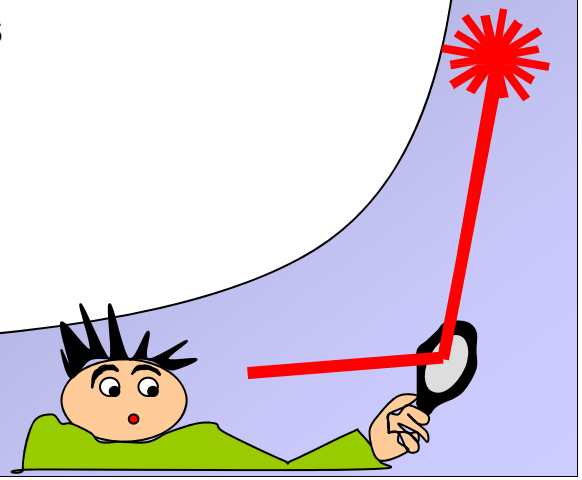
Laser operations and development for 32 years

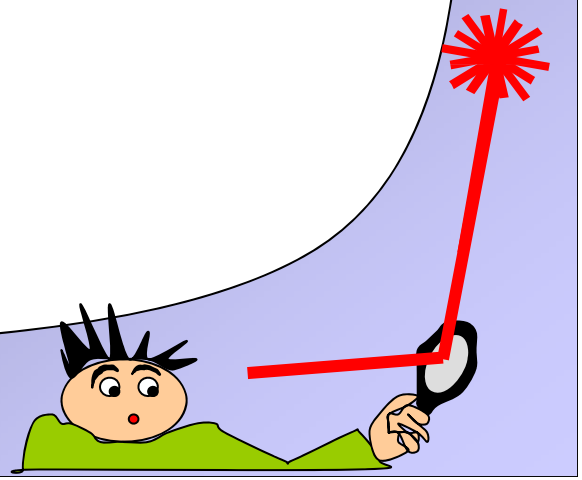
ANSI-certified Laser Safety Officer for 23 years



Practical laser safety in a university lab setting

Abstract:

University students are often expected to work with lasers having little or no formal laser safety training. We present guidelines for laser operators to ensure their own safety in a university lab setting.

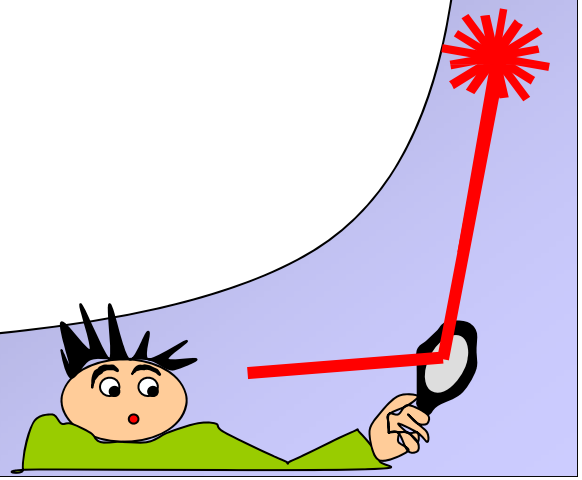


Practical laser safety in a university lab setting

Some slides were provided by Johnny Jones of Laser-Professionals (www.laser-professionals.com)

Laser-Professionals provides laser safety training and consultation services.

Laser-Professionals also provides a free Laser Hazard Analysis calculator – "EasyHaz" - on their website (see later discussion).



Practical laser safety in a university lab setting

University laser users are not subject to the same safety environment as at a national lab.

Obvious PROs:

No medical surveillance (never prevented an accident)

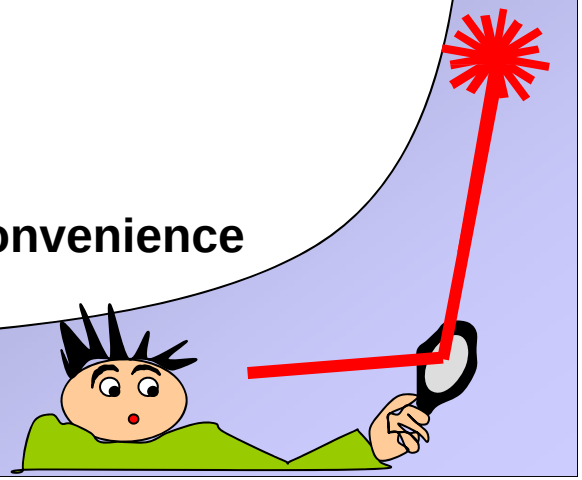
No compliance-driven requirements such as laser inventories, laser databases, specific labeling, etc (never prevented an accident)

No formalized written procedures (might be meaningless in ever-changing conditions)

No patronizing training

No formal reviews for trivial operations

Formalized safety is expensive in time, money, convenience



Practical laser safety in a university lab setting

University laser users are not subject to the same safety environment as at a national lab.

Obvious CONs:

No formal training requirements at all

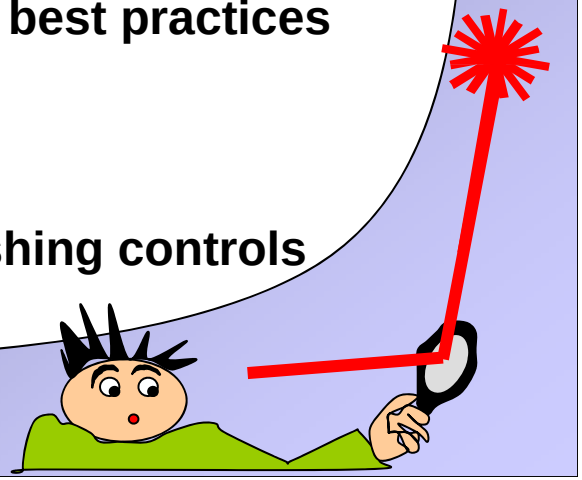
No formalized written procedures (safe work envelope, correct work procedures never clearly communicated)

No assurance that labs meet minimum standards

No communication about incidents, near misses, best practices

No standardized controls

No assistance with assessing hazards or establishing controls

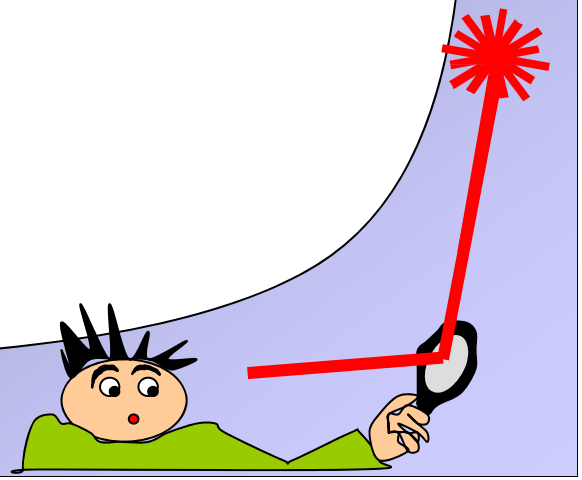


Practical laser safety in a university lab setting

University laser users are not subject to the same safety environment as at a national lab.

PRO or CON, depending upon your viewpoint:

Following established safety guidelines is a condition of employment at a national lab – whether the worker is a student or a mentor.



Practical laser safety in a university lab setting

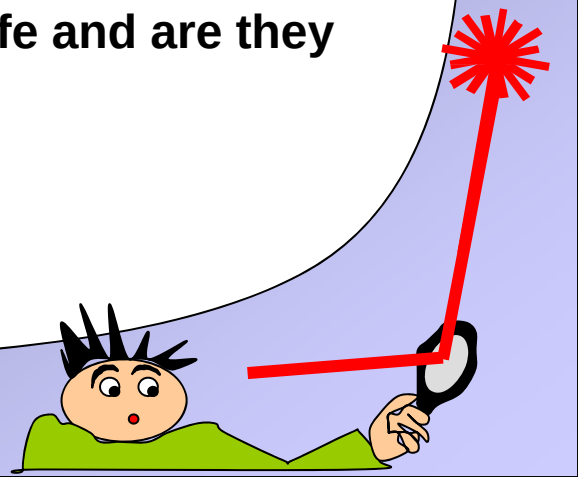
Absolute minimal safety precautions for a laser lab

Putting aside red tape, bureaucratic requirements, redundant overkill, one set of guidelines might be:

1. Are visitors, bystanders, passersby, coworkers protected from accidental exposure?

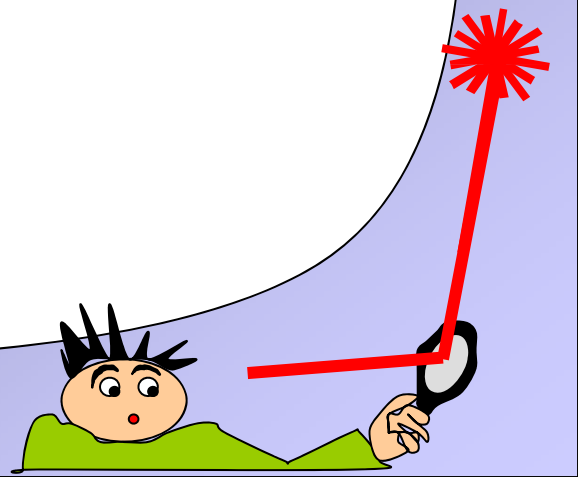
2. Does each person who works in the lab fully understand the hazards and how to mitigate them?

3. Does each person have the means to stay safe and are they free from pressure to cut safety corners?



Practical laser safety in a university lab setting

Are visitors, bystanders, passersby, coworkers protected from accidental exposure?



Practical laser safety in a university lab setting

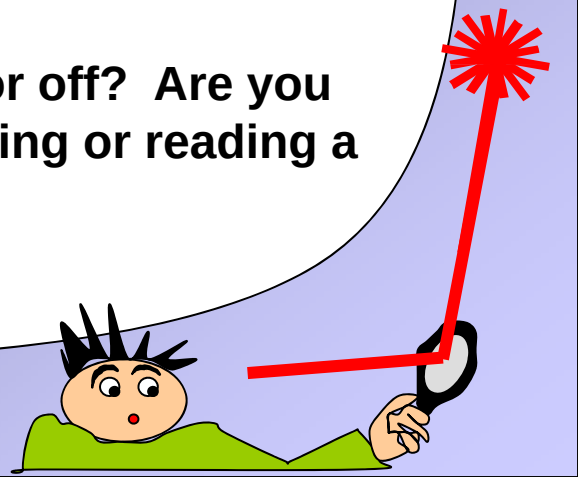
Are visitors, bystanders, passersby, coworkers protected from accidental exposure?

1. Could someone possibly wander into your lab by accident if a laser hazard is present?

   Janitor? Someone looking for a phone? Someone looking for a worker? Building trade worker? Emergency responder?

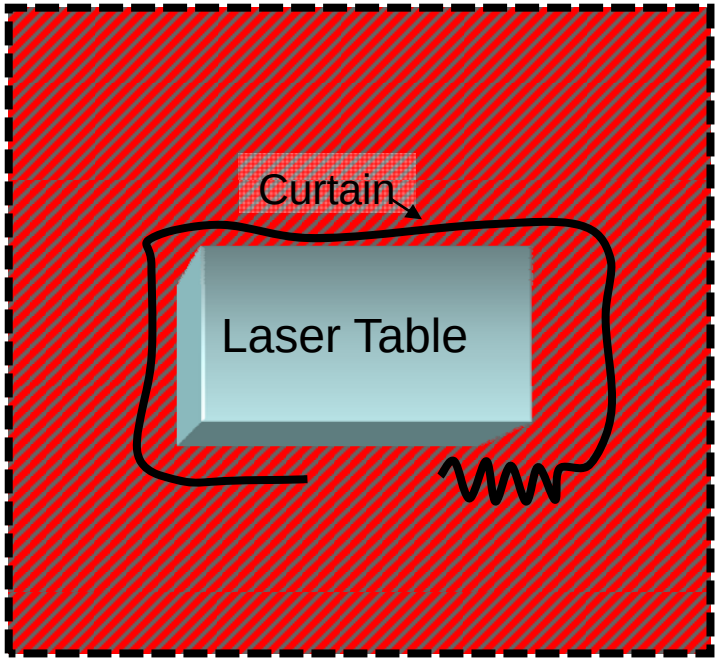
2. Could a worker wander into your lab without knowing there is a hazard?

   Is the signage the same whether the laser is on or off? Are you relying on perfect behavior for turning on a warning or reading a warning?



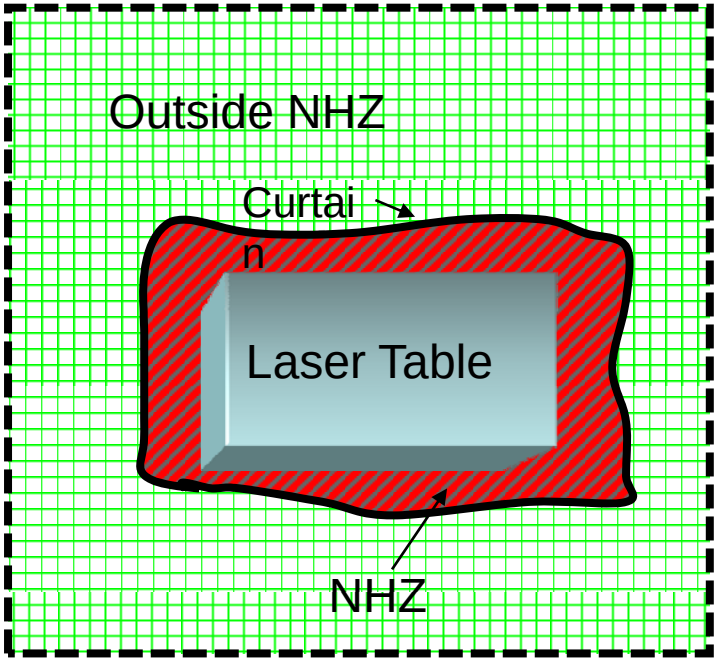
Practical laser safety in a university lab setting

Curtain Open:
Entire room is NHZ



LCA boundary (room walls)

Curtain Shut:
Most of room is *not* NHZ



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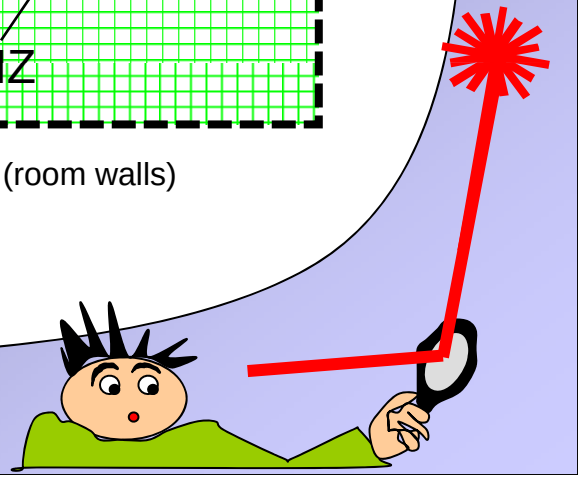
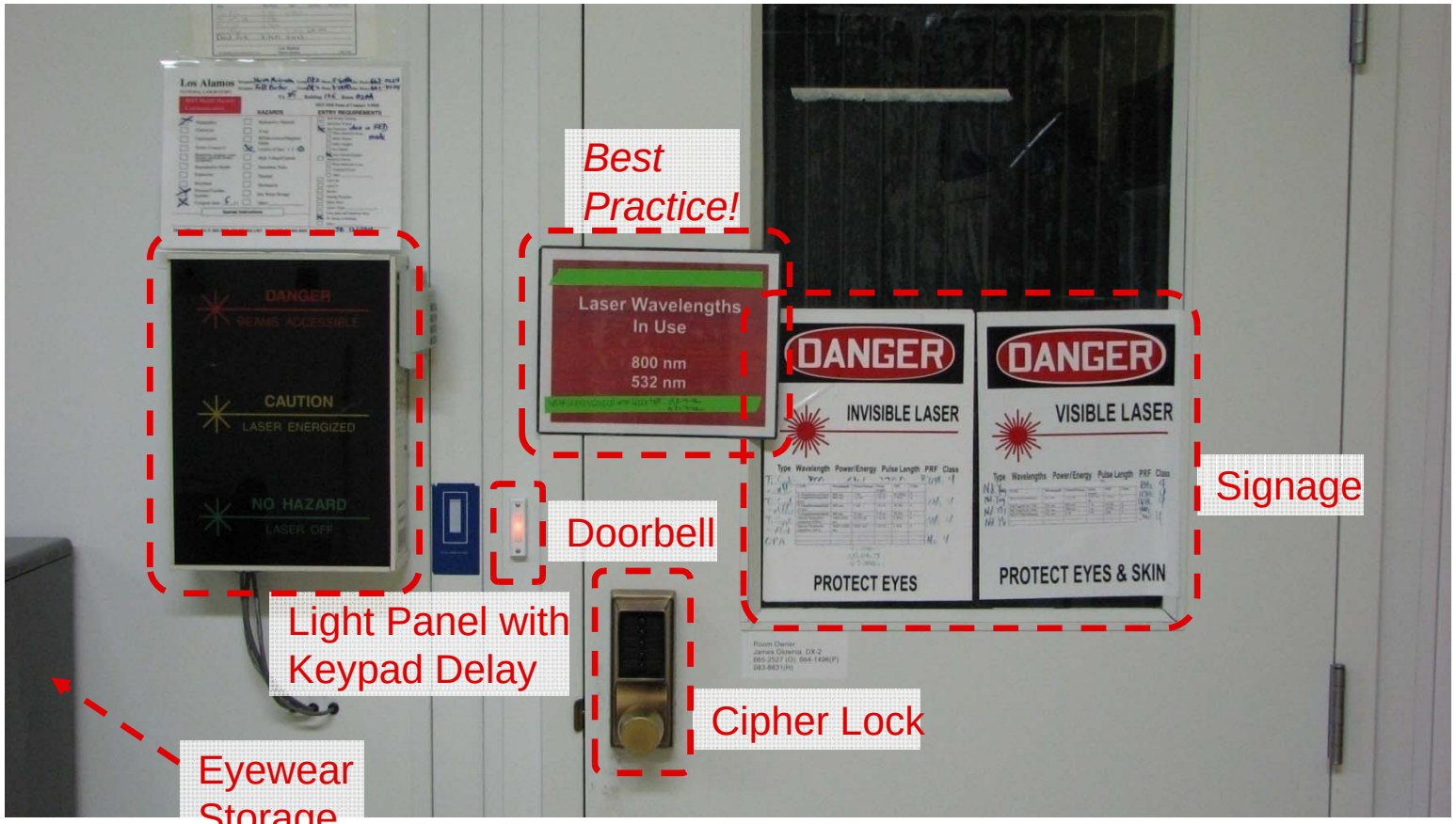
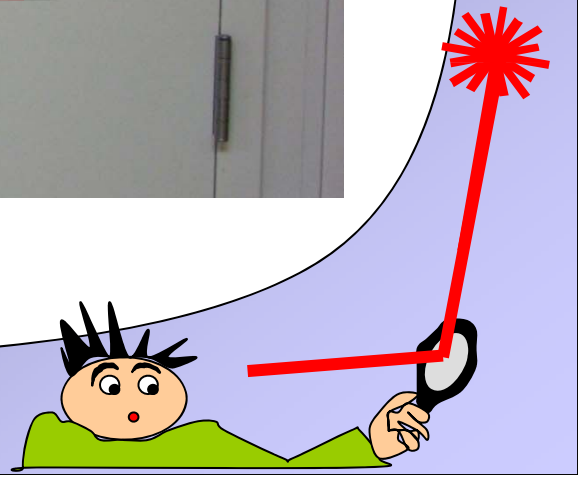


Practical laser safety in a university lab setting





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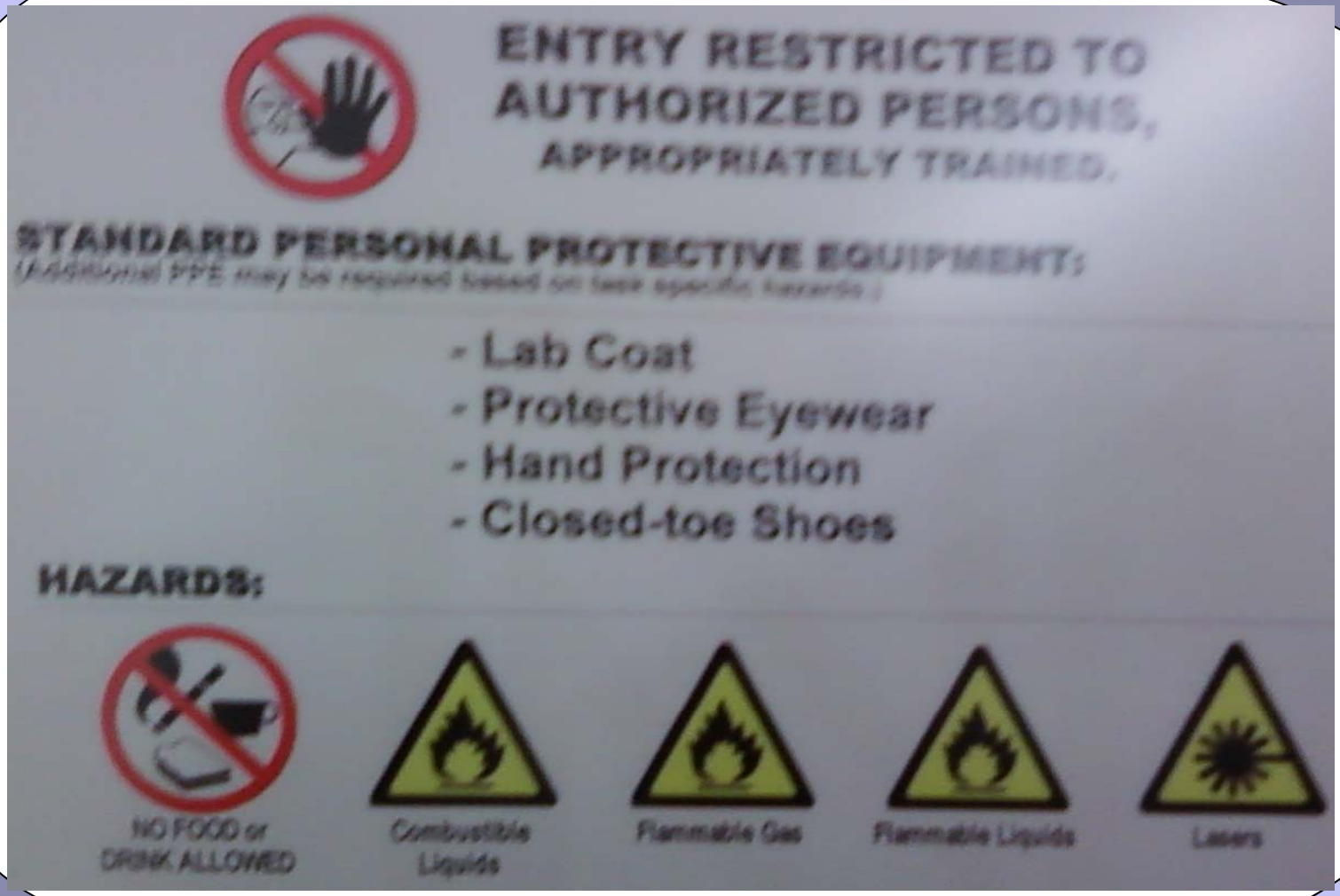
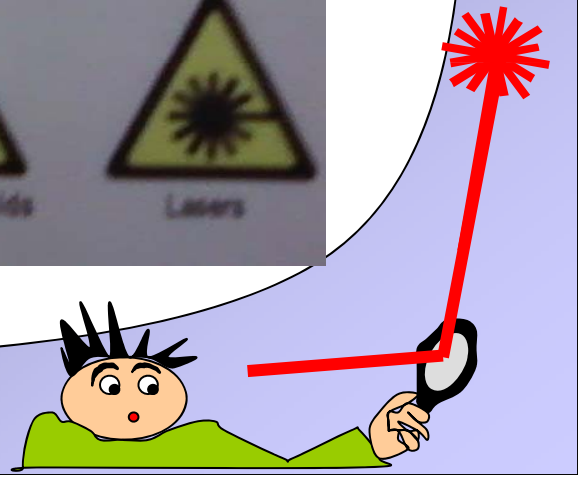


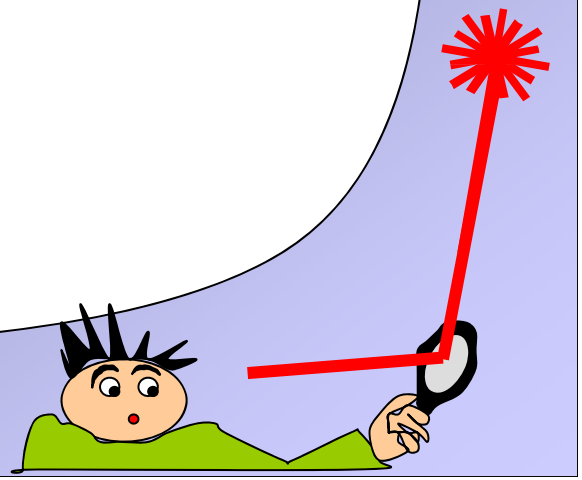


Practical laser safety in a university lab setting

Are coworkers protected from accidental exposure?

Could coworkers or worker sharing your lab space be exposed to laser beams?

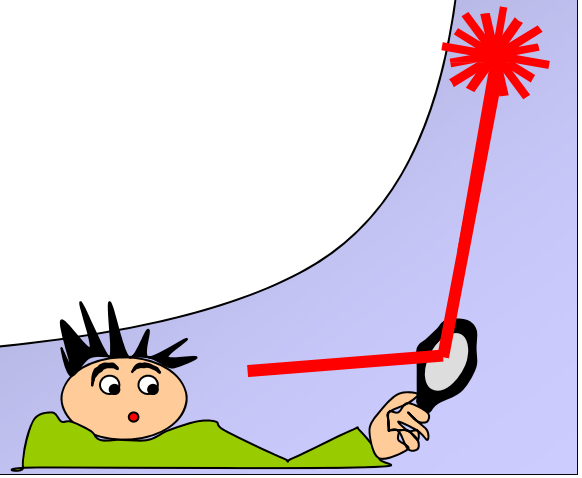
Are controls in place to prevent beams from leaving the laser table? Do you sweep the lab regularly for stray beams? Do you know the Nominal Hazard Zone for diffuse reflections in your lab and designed appropriate controls?



Practical laser safety in a university lab setting

Entryway curtain:

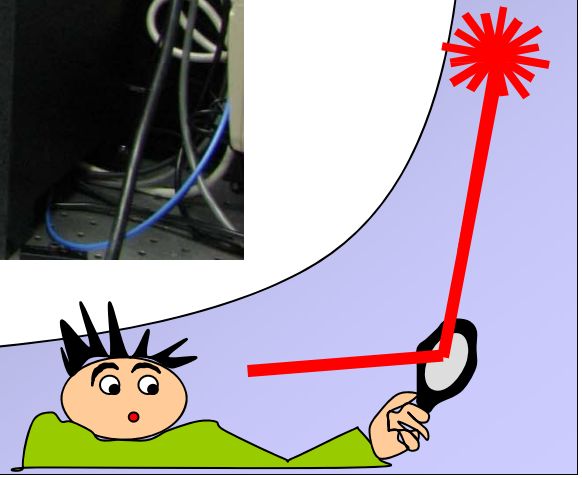
Prevents beam(s) from striking personnel at entryway when door is opened



Practical laser safety in a university lab setting

Table curbs:

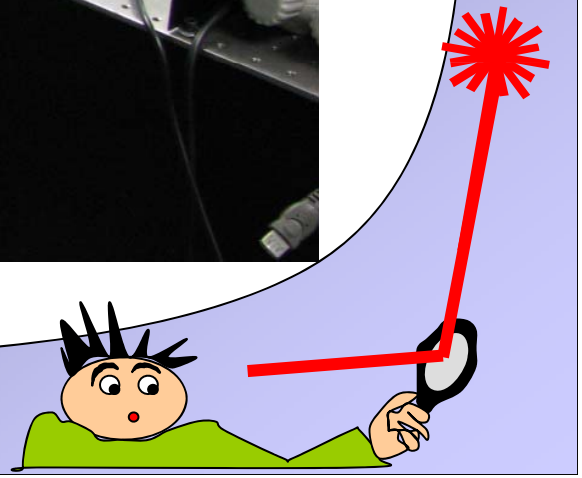
Protect incidental personnel



Practical laser safety in a university lab setting

Lab ergonomics:

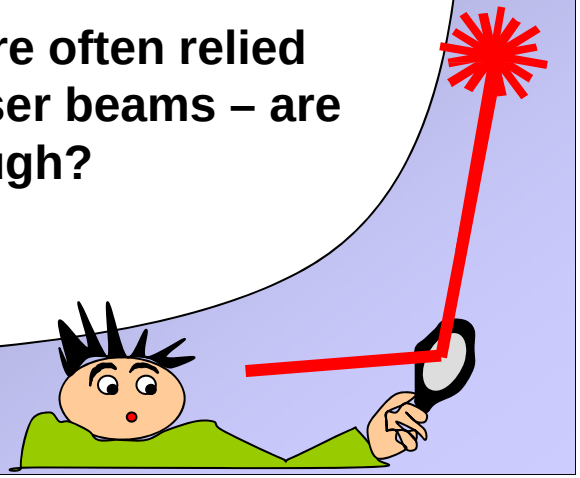
Chairs, workspaces do not put workers at eye level with the beams.
Easily moveable barriers are readily available and used to isolate dangerous areas



Practical laser safety in a university lab setting

Optical elements must be firmly affixed:

Optical elements are often relied upon to confine laser beams – are yours reliable enough?



Practical laser safety in a university lab setting

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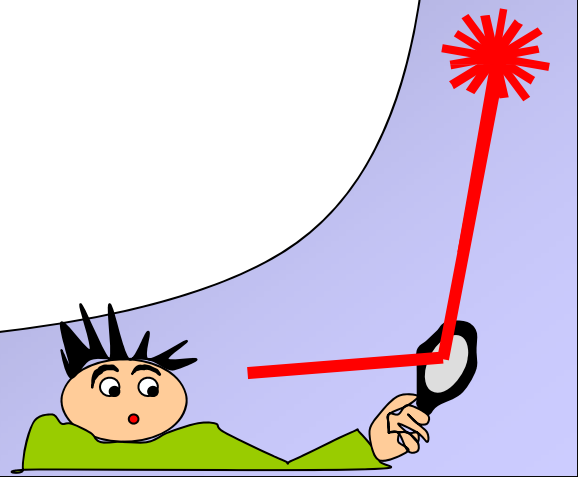
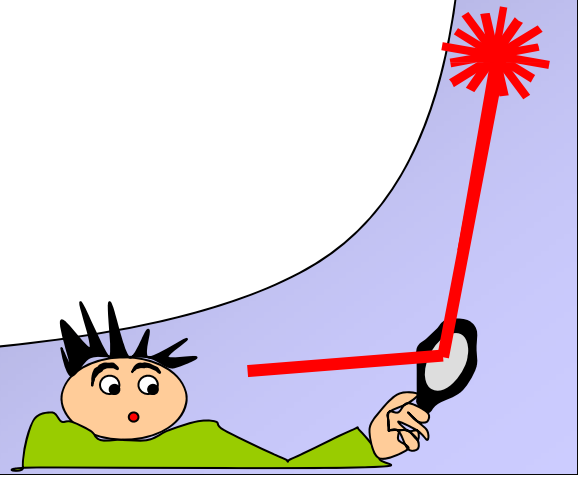


Practical laser safety in a university lab setting

Does each person who works in the lab fully understand the hazards and how to mitigate them?



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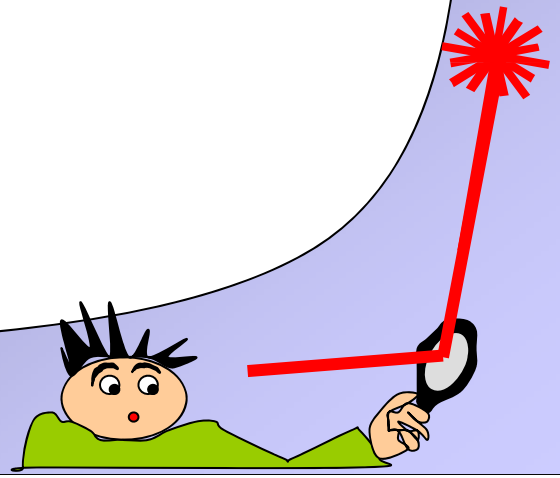
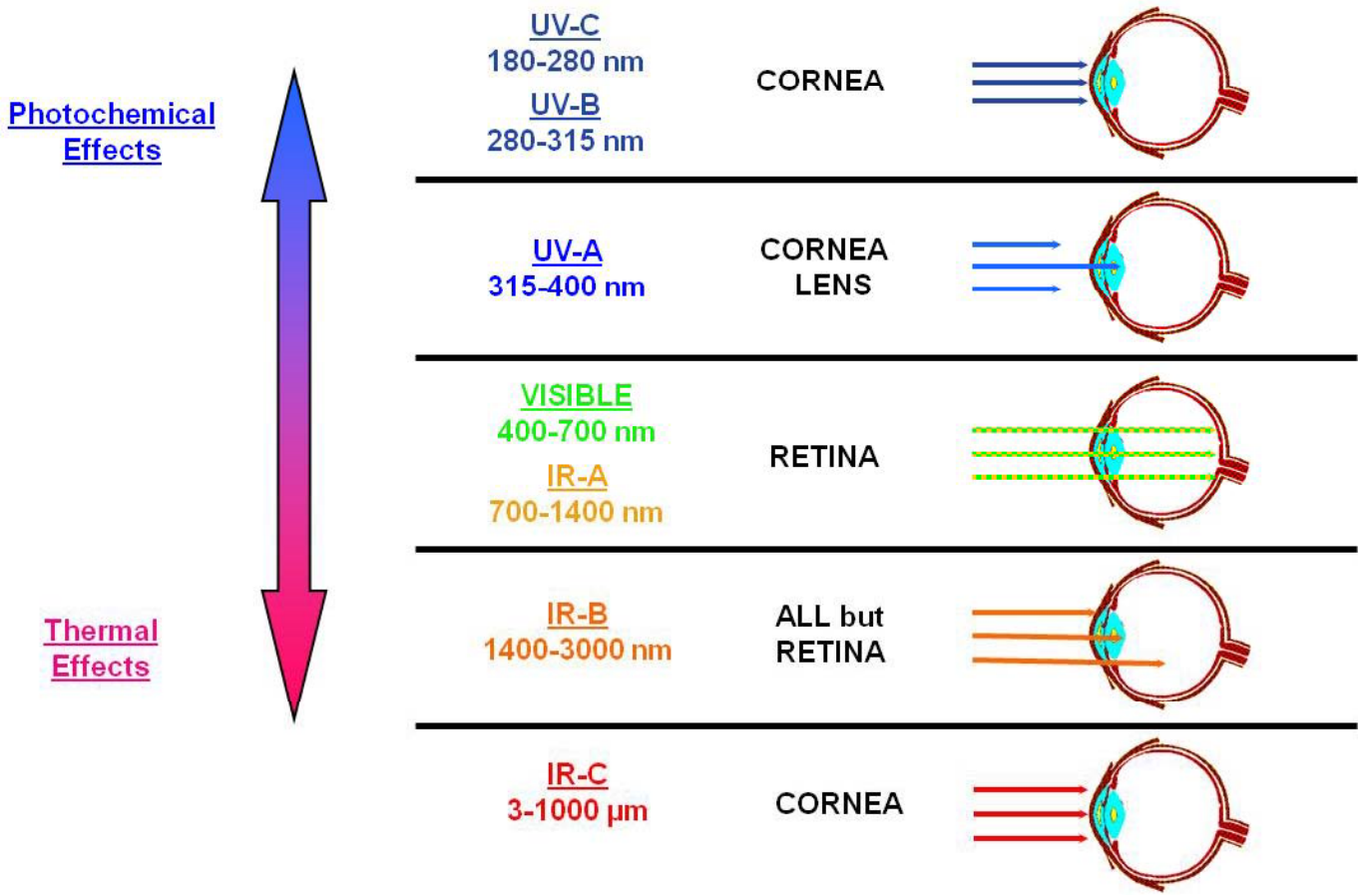
NON-BEAM HAZARDS

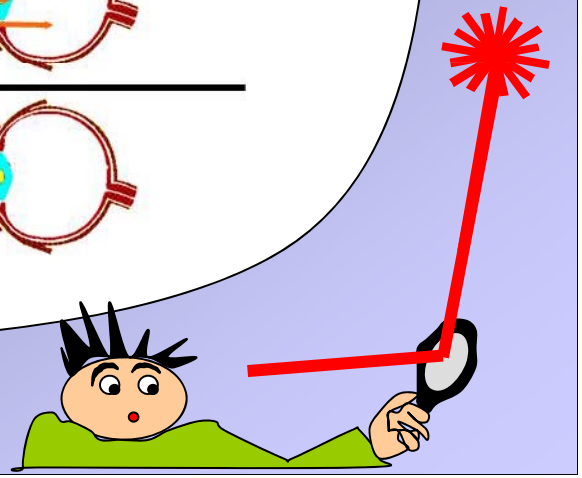
- Electrical Hazards
- Smoke & Fumes
- Mechanical Hazards
- Process Radiation
- Flashlamp Light
- Chemical Hazards



Practical laser safety in a university lab setting

Mechanisms for laser injury





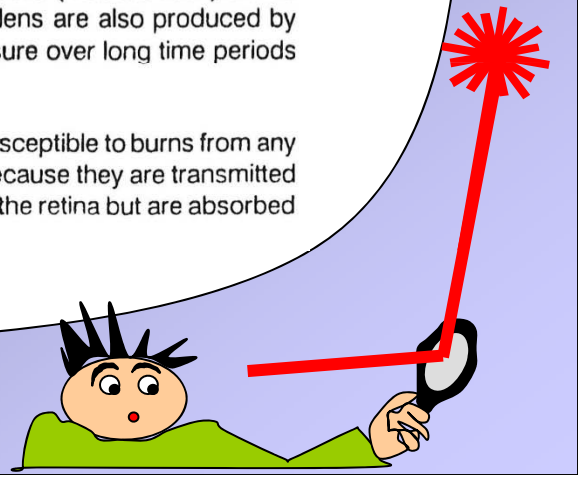
Practical laser safety in a university lab setting

LASER EFFECTS

BAND	UV - C	UV - B	UV - A	VISIBLE	IR - A	IR - B	IR - C
WAVELENGTH IN μm.	0.1	0.28	0.315	0.4	0.76	1.4	3.0 — 10.0
ADVERSE EFFECTS	PHOTOKERATITIS			RETINAL BURNS			CORNEAL BURNS
		CATARACTS				CATARACTS	
	ERYTHEMA			COLOR & NIGHT VISION DEGRADATION			
			THERMAL SKIN BURNS				

Adverse biological reactions to laser exposures varies according to the laser wavelength. Photokeratitis (welders flash) on the cornea and erythema (sunburn) on skin are produced by ultraviolet energy. Cataracts of the eye lens are also produced by ultraviolet. These effects are accumulative over long periods of time. Thus even low levels of exposure over long time periods produce adverse effects. The reaction may be delayed and occur several hours after exposure.

Thermal effects (burns from intense heat) are produced by nearly any laser wavelength. The skin is susceptible to burns from any wavelength. Light waves in the range from 0.4 μm to 1.4 μm are particularly dangerous to the eye because they are transmitted through the lens system and are focused on the retina. Wavelengths longer than 1.4 μm do not reach the retina but are absorbed on the cornea.



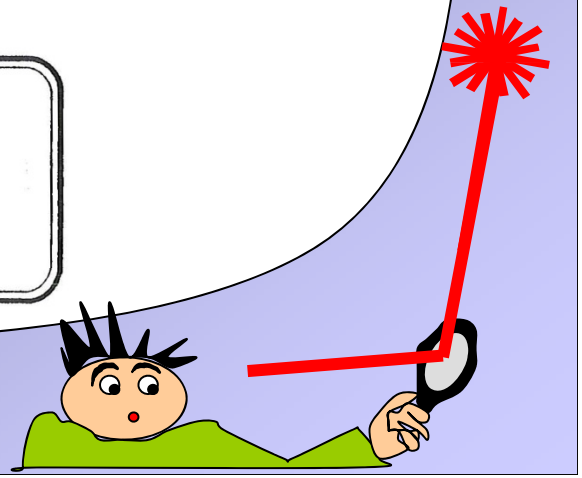
Practical laser safety in a university lab setting

LASER EFFECTS

THERMAL:
- Caused by elevated temperature after absorption of laser energy.
- Nearly all wavelengths and exposure durations.

PHOTOCHEMICAL:
- Caused by chemical reactions within body tissue after absortion of laser energy.
- Only with wavelengths less than .550 μm.
- Exposure duration greater than 10 seconds.

SHOCKWAVE (ACOUSTIC):
- An explosive effect when short pulses are absorbed on the retina.
- Pulse duration less 10μ seconds.



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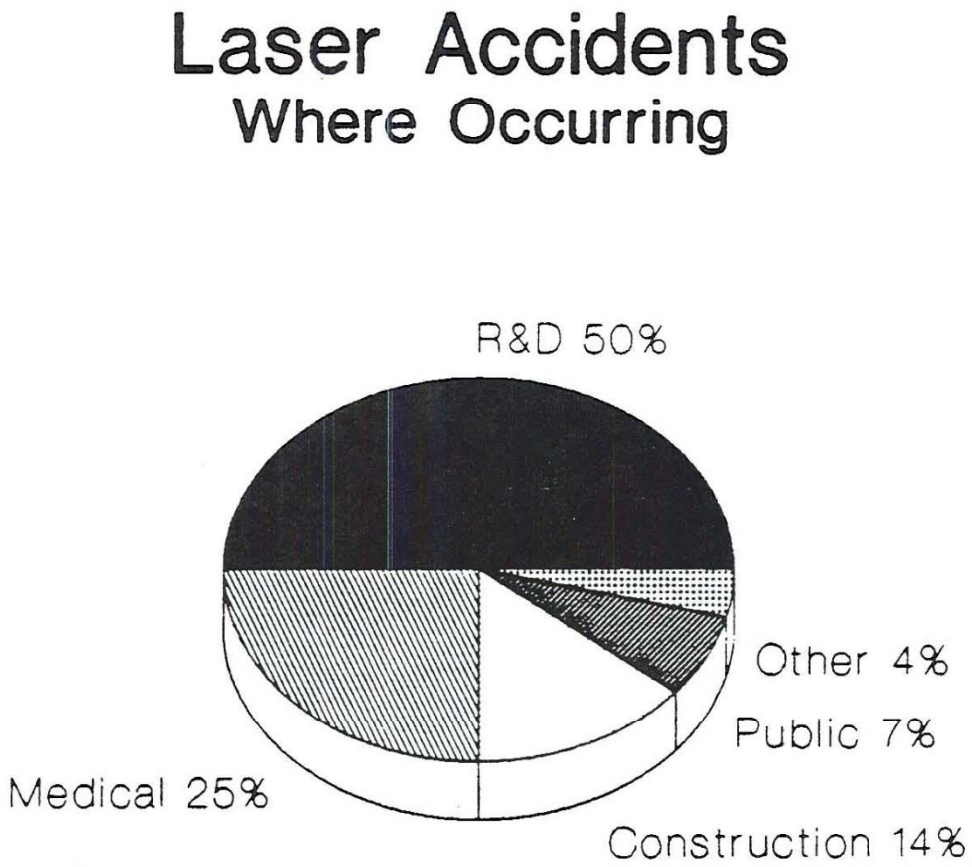
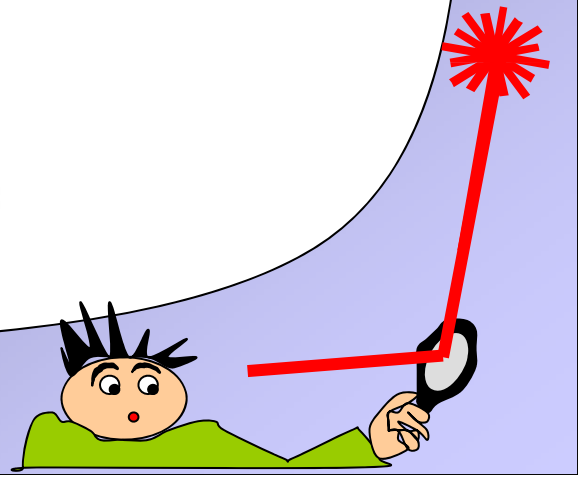
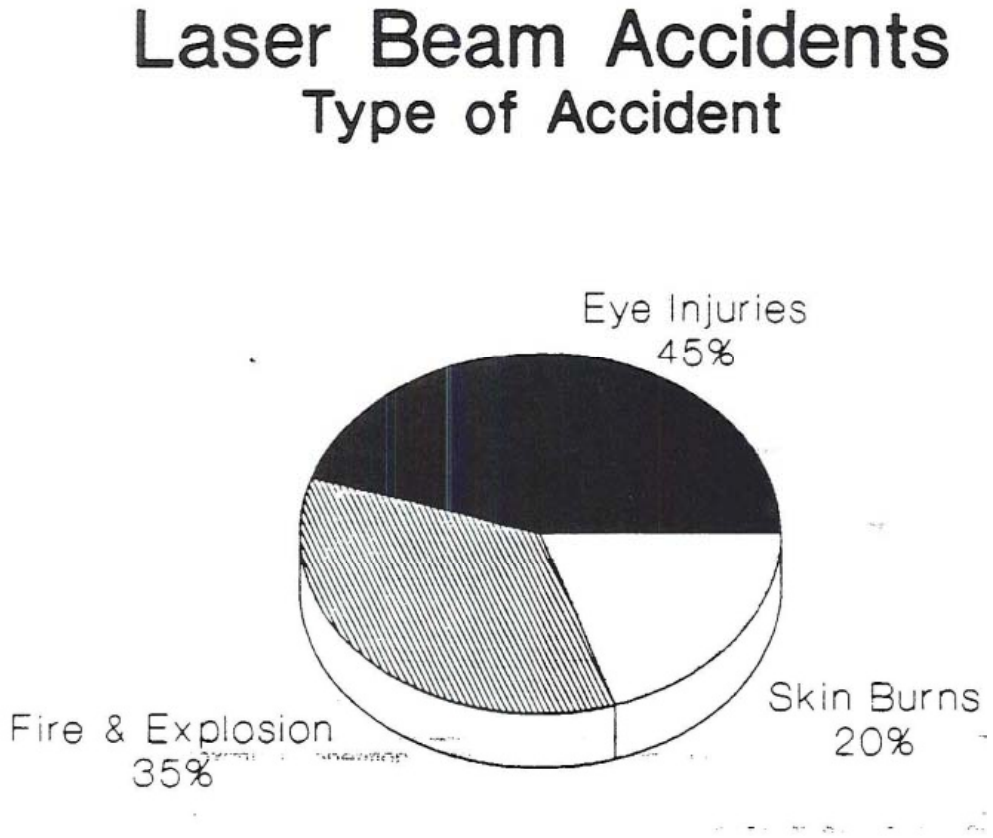
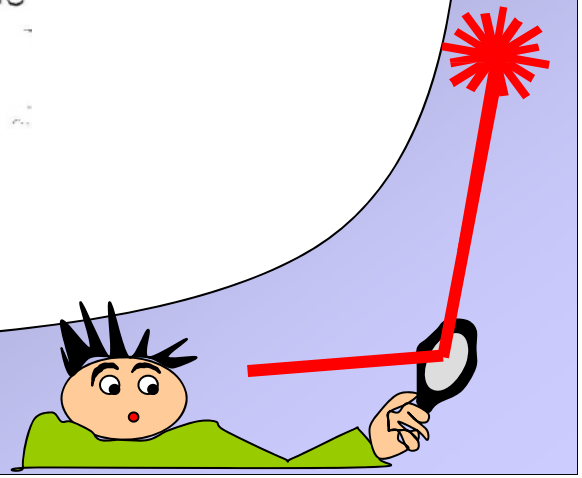




Practical laser safety in a university lab setting

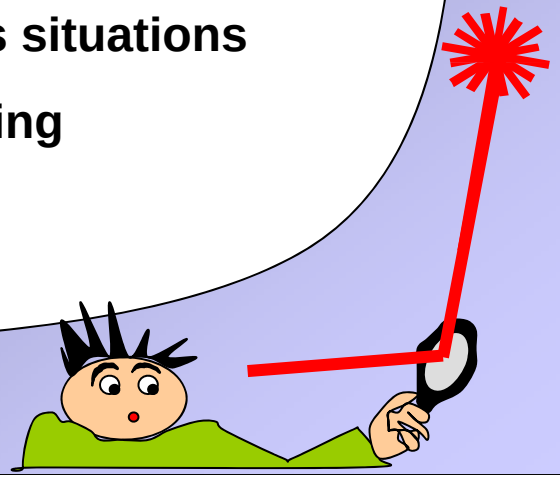




CAUSES OF LASER ACCIDENTS

Studies of laser accidents have shown that there are usually several contributing factors. The following are common causes of laser injuries:

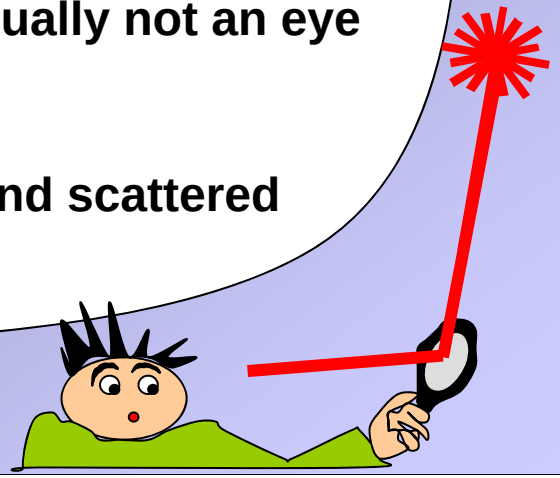
- **Inadequate training of laser personnel**
- **Alignment performed without adequate procedures**
- **Failure to block beams or stray reflections**
- **Failure to wear eye protection in hazardous situations**
- **Failure to follow approved standard operating procedures or safe work practices**



Practical laser safety in a university lab setting

LASER CLASSIFICATION SUMMARY

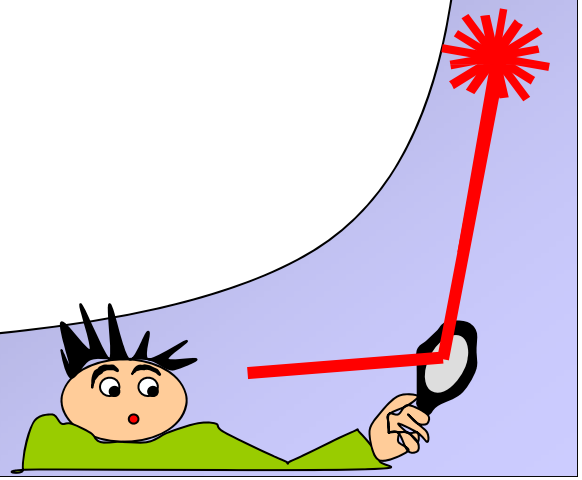
Class 1	**Incapable of causing injury during normal operation**
Class 1M	Incapable of causing injury during normal operation unless collecting optics are used
Class 2	**Visible lasers incapable of causing injury in 0.25 s.**
Class 2M	Visible lasers incapable of causing injury in 0.25 s unless collecting optics are used
Class 3R	Marginally unsafe for intrabeam viewing; up to 5 times the class 2 limit for visible lasers or 5 times the class 1 limit for invisible lasers
Class 3B	**Eye hazard for intrabeam viewing, usually not an eye hazard for diffuse viewing**
Class 4	**Eye and skin hazard for both direct and scattered exposure**



Practical laser safety in a university lab setting

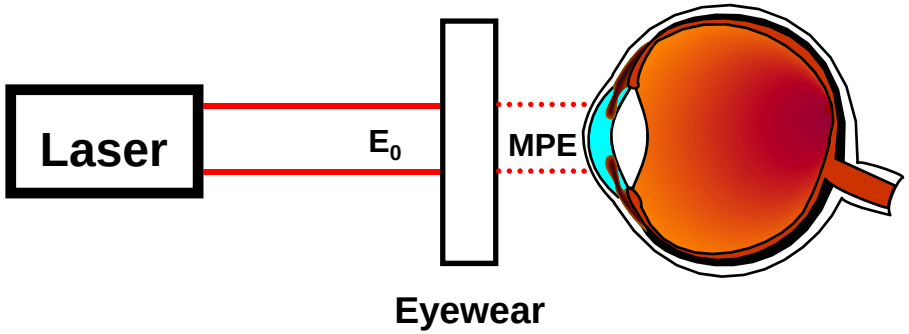
Does each person who works in the lab fully understand the hazards and how to mitigate them?

LASER HAZARD EVALUATION

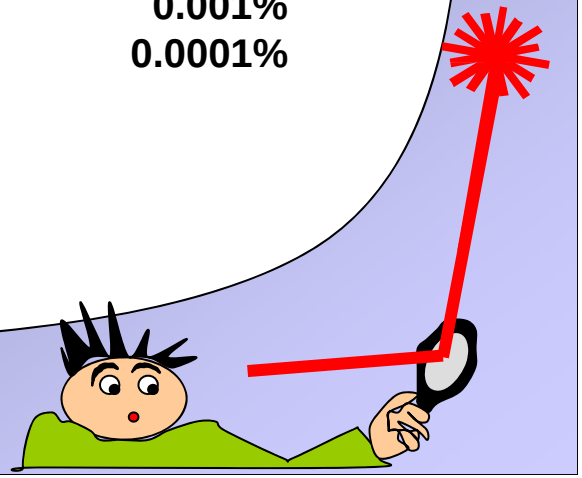


Practical laser safety in a university lab setting

OPTICAL DENSITY OF LASER SAFETY EYEWEAR



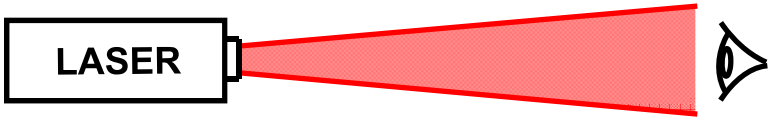
OD	% Transmission
0	100%
1	10%
2	1%
3	0.1%
4	0.01%
5	0.001%
6	0.0001%



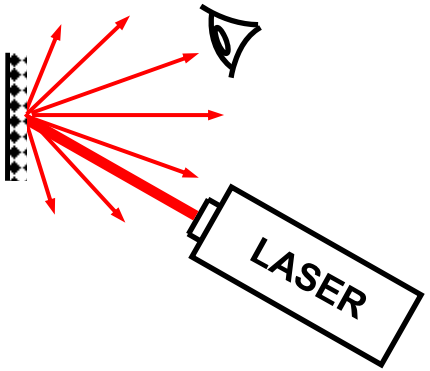
Practical laser safety in a university lab setting

NOMINAL HAZARD ZONE

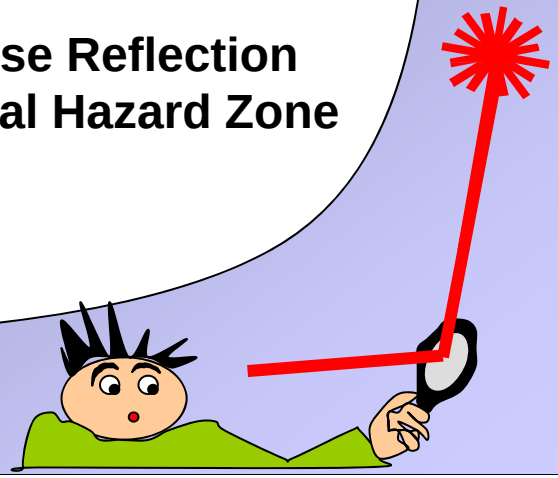
The space within which the potential exposure exceeds the Maximum Permissible Exposure.



Intrabeam
Nominal Hazard Zone



Diffuse Reflection
Nominal Hazard Zone



Practical laser safety in a university lab setting

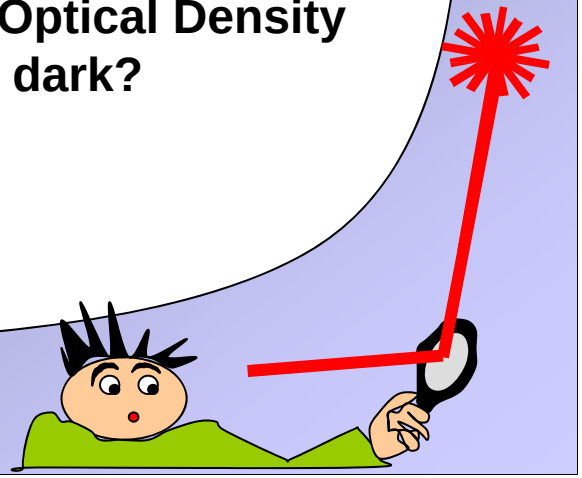
Can you evaluate the laser hazard and choose appropriate eyewear for your work?

Do you want to entrust your eyesight to someone else's judgment?

Is the eyewear adequate?

Goggles exhibit herding behavior - inappropriate eyewear tends to collect in piles. Are you using the correct pair?

Does your eyewear discourage use? Does it have Optical Density or spectrum overkill, is it uncomfortable or overlay dark?



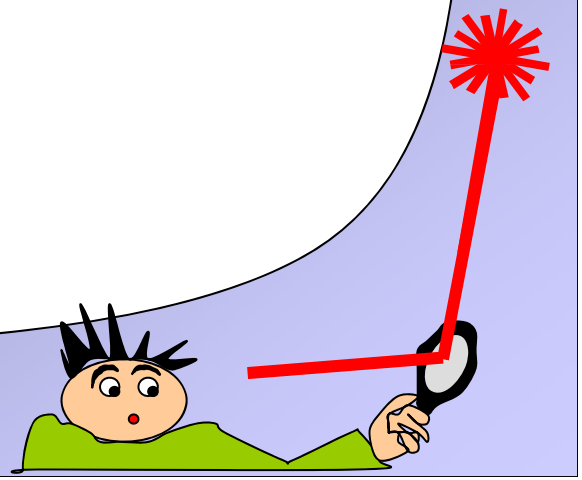
Practical laser safety in a university lab setting

For choosing eyewear, the minimum information needed:

Laser wavelength

Power and timing (if continuous, Watts
if pulsed, Joules per pulse, pulse length, rep rate)

Exposure time (0.25 s for visible; 10 s for casual exposure to
invisible beams; 30,000 for workday exposure)



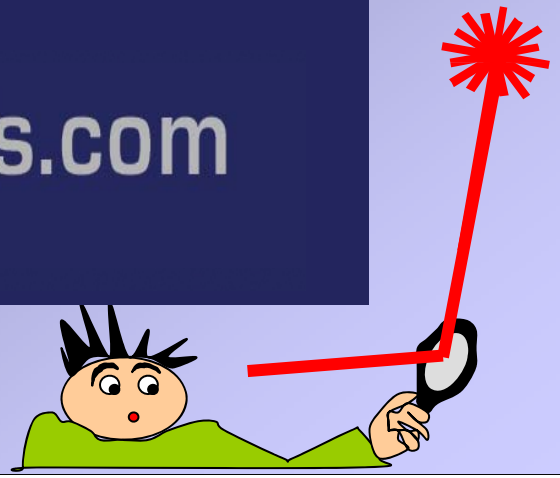
Practical laser safety in a university lab setting

FREE

LASER HAZARD ANALYSIS SOFTWARE

EASY HAZ©

www.laser-professionals.com



Practical laser safety in a university lab setting

Easy Haz v1.5 http://www.laser-professionals.com/resources/easyhazweb.htm

Messages

LASER

Wavelength Units: nanometer

Wavelength: 632.000

Mode of Operation: continuous wave

LASER-PROFESSIONALS Inc.
Where the laser user comes first

RANGE INFORMATION

PARAMETERS

Min: 1E-15 W	Max: 1E+23 W	Power :	W
Min: 1E-18 s	Max: 30000 s	Exposure Duration :	s
	entry ignored	**********	
	entry ignored	**********	
Min: 1E-3 mm	Max: 1E+4 mm	Beam Diameter :	mm
Min: 1E-5 mrad	Max: 1E+3 mrad	Beam Divergence :	mrad
		Measurement Criteria : (1/e^2)	

EASY HAZ

REPORT

Small Source Ocular MPE :
Optical Density of Eyewear :
Diffuse Reflection NHZ :
Intrabeam NOHD :

Click for EASY HAZ tutorial and all the EASY HAZ software family

For your Laser Safety needs visit our friends at the Kentek Laser Store

Easy Haz is intended for educational and informational purposes and is not a substitute for a knowledgeable and trained Laser Safety Officer as required by ANSI Z136.1 American National Standard for Safe Use of Lasers.

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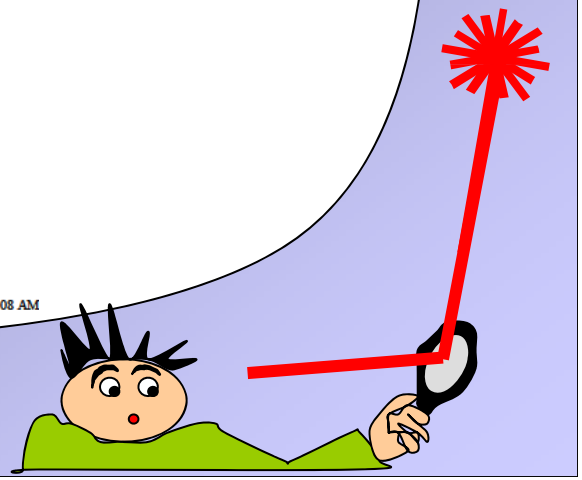


Practical laser safety in a university lab setting

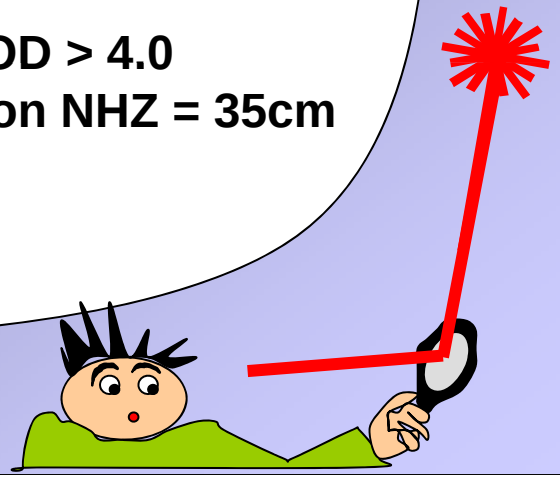
Sample Results:

λ = 800nm
E = 1mJ/pulse
pulse length = 40fs
rep rate = 10kHz
exposure time = 10 s

Need eyewear OD > 4.8
diffuse reflection NHZ = 85cm

λ = 532nm
power = 10W
exposure time = 0.25 s

Need eyewear OD > 4.0
diffuse reflection NHZ = 35cm

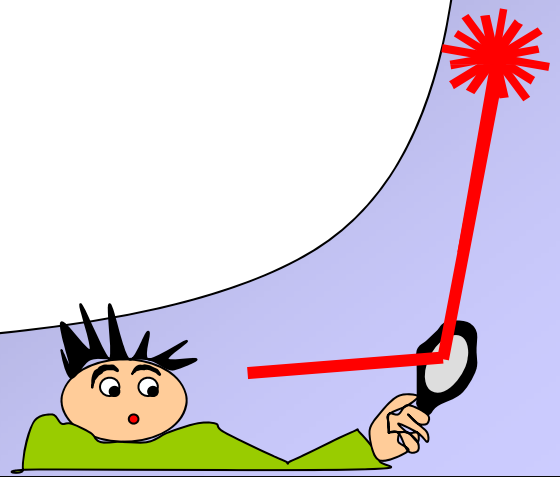


Practical laser safety in a university lab setting

Safety eyewear

Laser work is dangerous enough that multiple layers of protection are required.

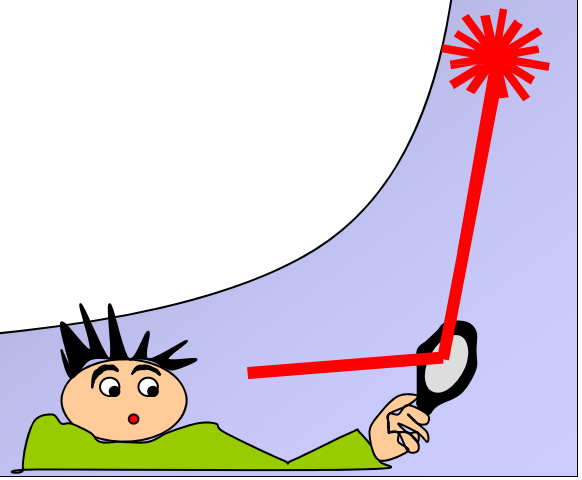
Thus, laser eyewear is an important complement to safe procedures in a laser lab.



Practical laser safety in a university lab setting

You DON’T need eye protection if:

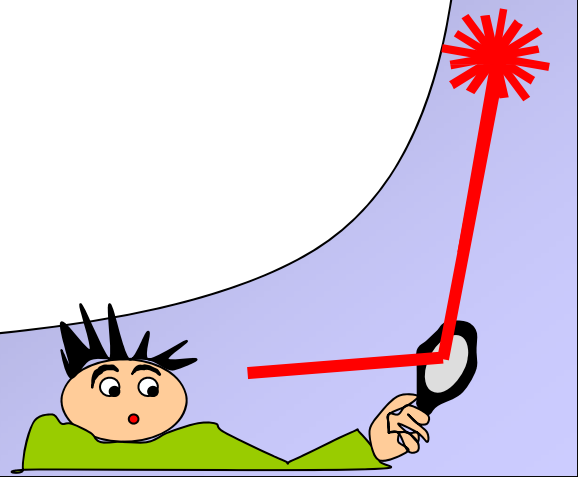
1. **A lab accident only affects you and nobody else**



Practical laser safety in a university lab setting

You DON’T need eye protection if:

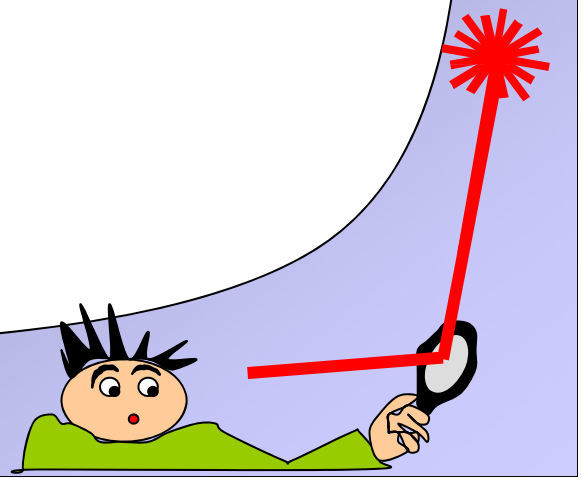
1. A lab accident only affects you and nobody else
2. Nobody else learns from examples you set



Practical laser safety in a university lab setting

You DON’T need eye protection if:

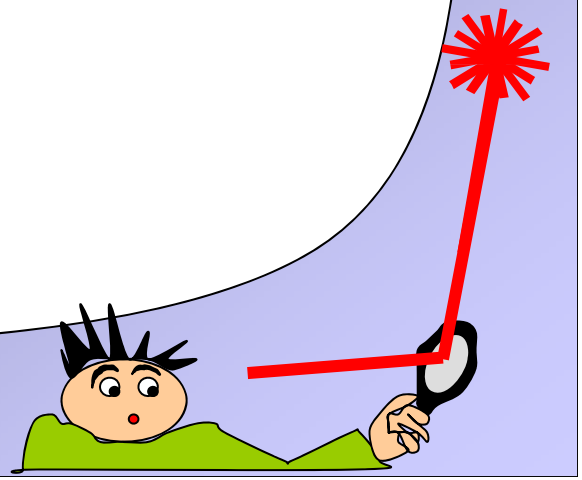
1. A lab accident only affects you and nobody else
2. Nobody else learns from examples you set
3. You never make a mistake



Practical laser safety in a university lab setting

You DON’T need eye protection if:

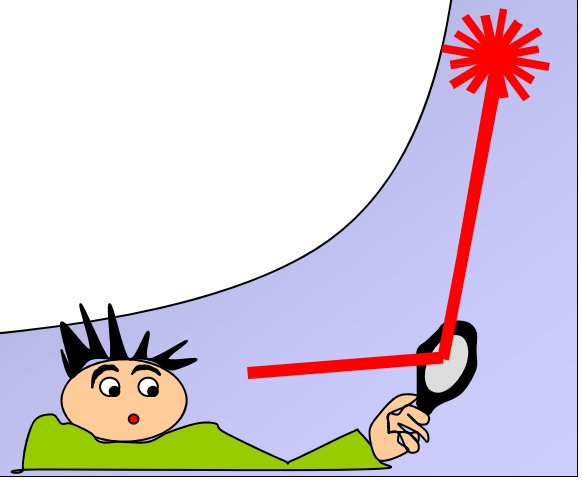
1. A lab accident only affects you and nobody else
2. Nobody else learns from examples you set
3. You never make a mistake
4. Your lab partners never make mistakes



Practical laser safety in a university lab setting

You DON’T need eye protection if:

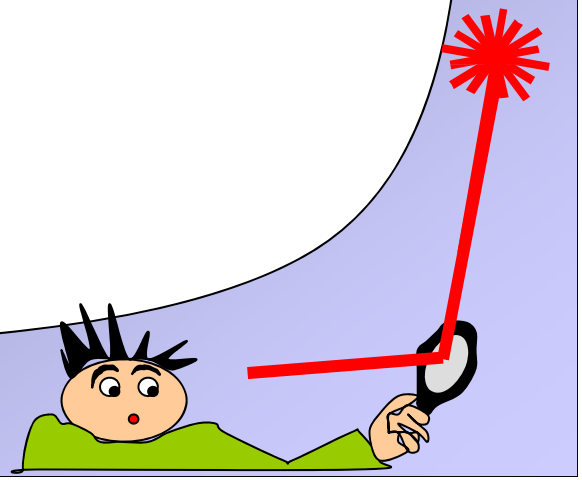
1. A lab accident only affects you and nobody else
2. Nobody else learns from examples you set
3. You never make a mistake
4. Your lab partners never make mistakes
5. You can see a laser beam in mid-air



Practical laser safety in a university lab setting

You DON’T need eye protection if:

1. A lab accident only affects you and nobody else
2. Nobody else learns from examples you set
3. You never make a mistake
4. Your lab partners never make mistakes
5. You can see a laser beam in mid-air
6. You have excellent vision in the ultraviolet and infrared



Practical laser safety in a university lab setting

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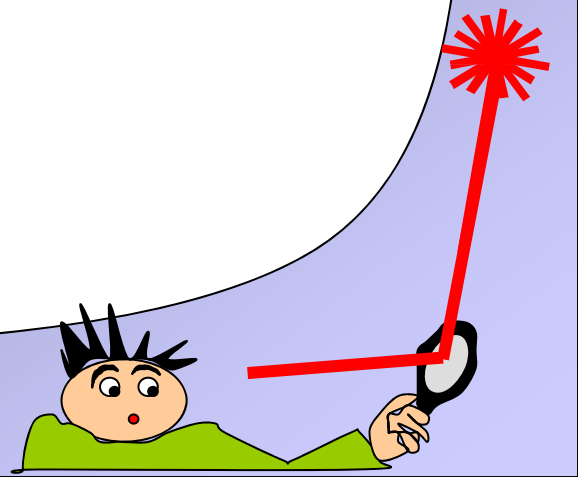
6. You have excellent vision in the ultraviolet and infrared
7. You have titanium-coated eyeballs



Practical laser safety in a university lab setting

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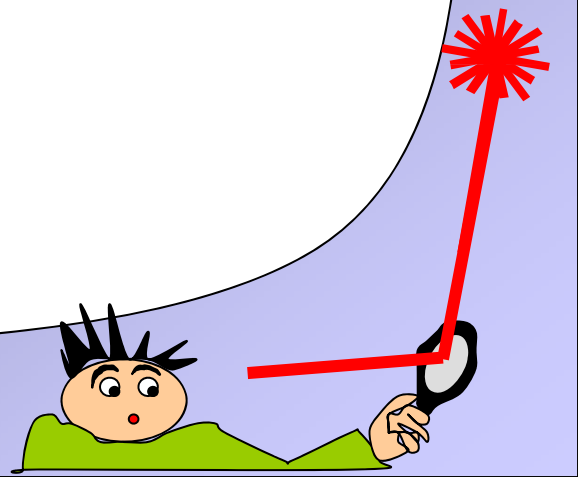
3. You never make a mistake
4. Your lab partners never make mistakes
5. You can see a laser beam in mid-air
6. You have excellent vision in the ultraviolet and infrared
7. You have titanium-coated eyeballs
8. You’re overwhelmed by four sensory inputs as it is



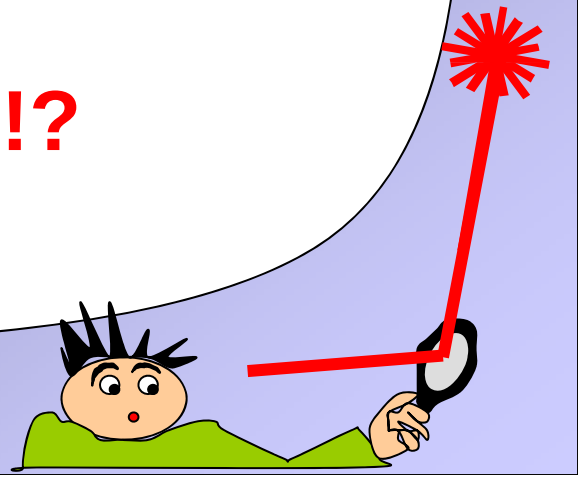
Practical laser safety in a university lab setting

You DON'T need eye protection if:

You understand the implications of injuring your eye and are willing to take the risk

(This is NOT a valid reason at a national lab. At a university, this is up to each lab advisor)

?! Open for debate !!?

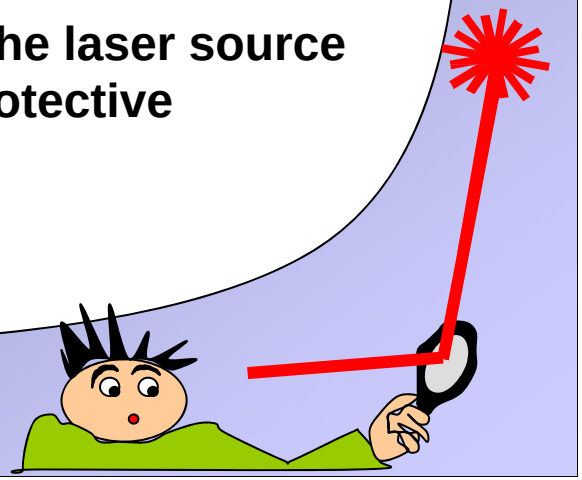


Practical laser safety in a university lab setting

Does each person who works in the lab fully understand the hazards and how to mitigate them?

Special hazards may include:

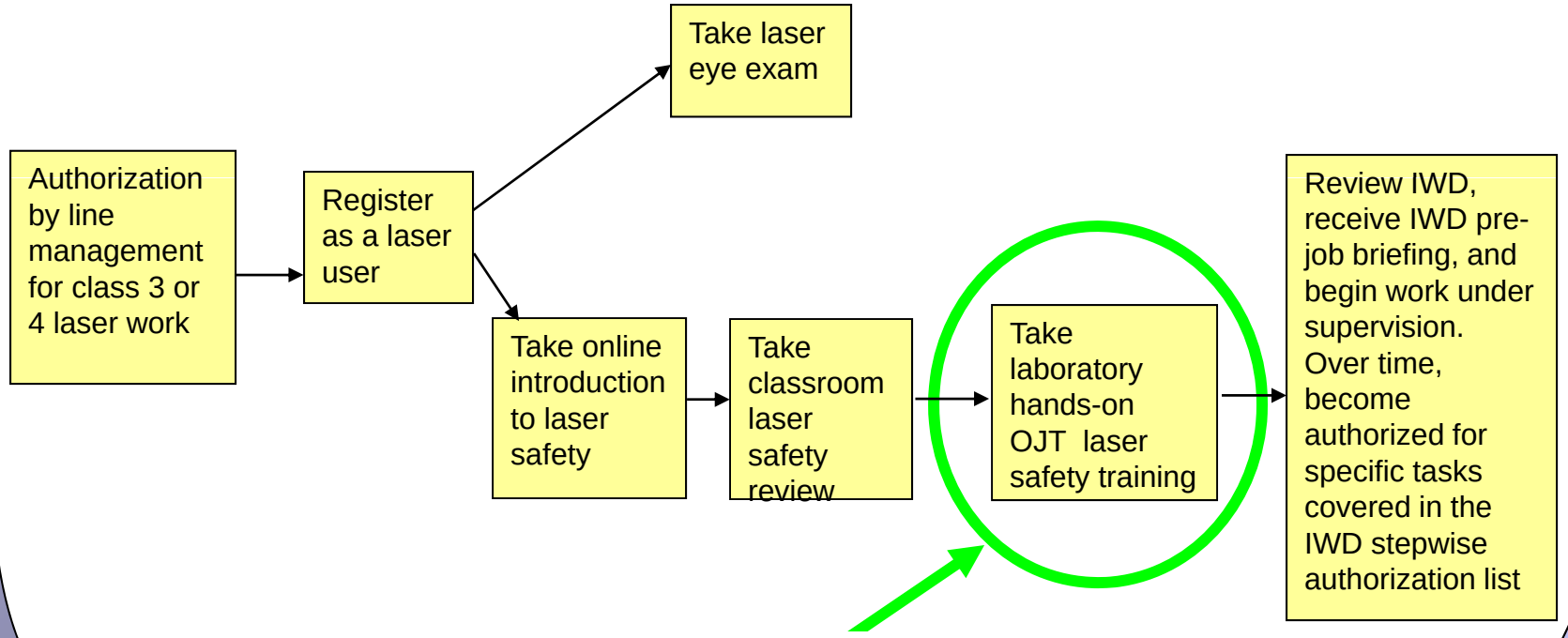
- * multiple experiments in a single lab
- * multiple laser beams in a lab or on a single table
- * invisible laser beams (uv or infrared)
- * outside laser operations, such as LIDAR
- * beams that cross walkways
- * the need to wear especially dark goggles
- * work on fibers or beamlines remote from the laser source
- * internal alignment of laser cavities with protective covers removed



Practical laser safety in a university lab setting

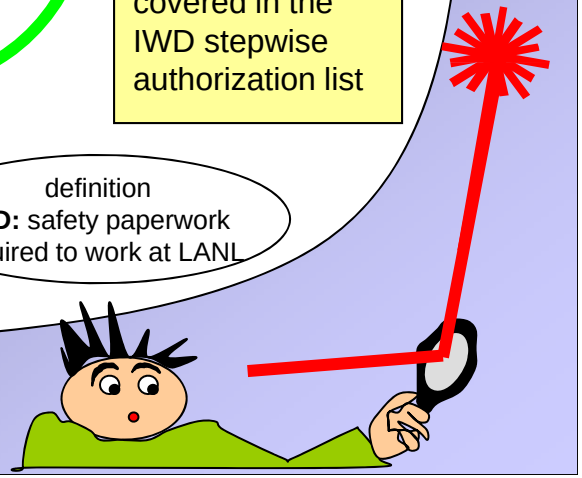
Procedural controls for laser hazard mitigation:

Training plan for new laser users at Los Alamos



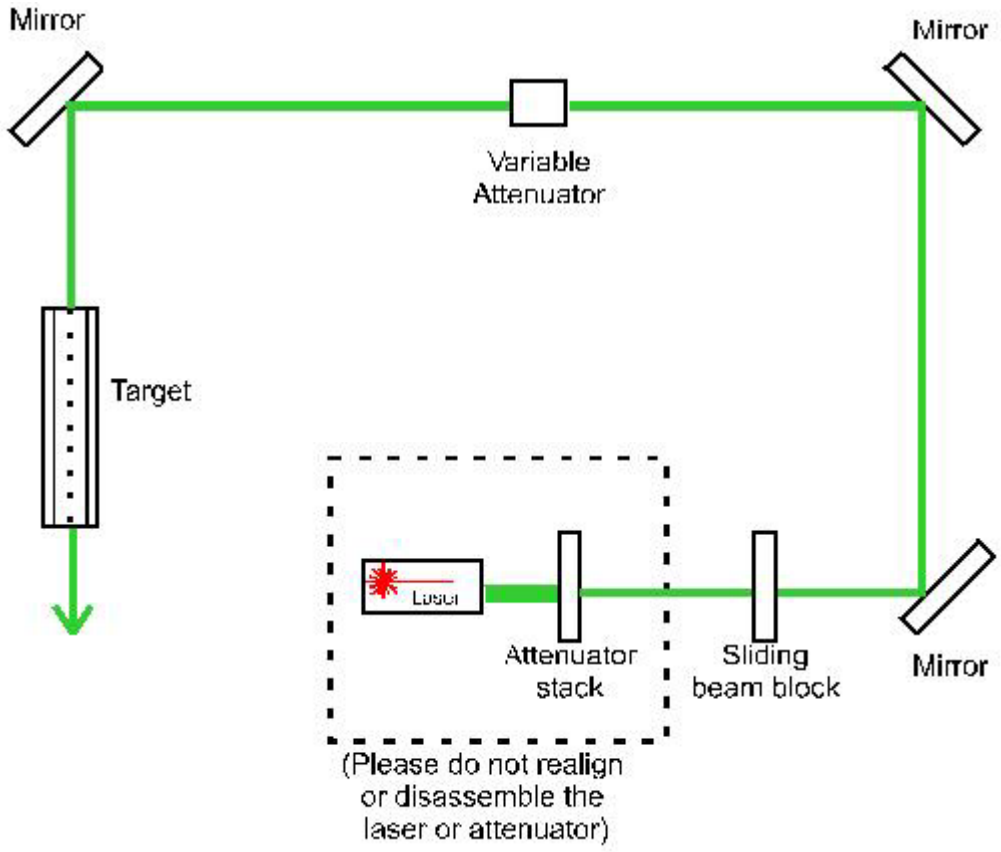
I designed, wrote, and teach this class

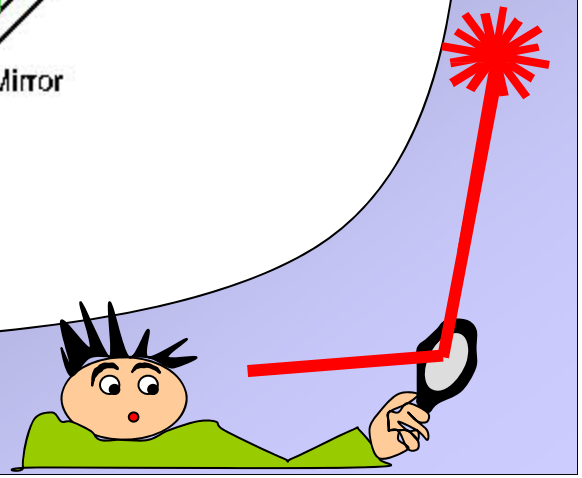
definition
IWD: safety paperwork required to work at LANL



Practical laser safety in a university lab setting

Laser alignment exercise #1





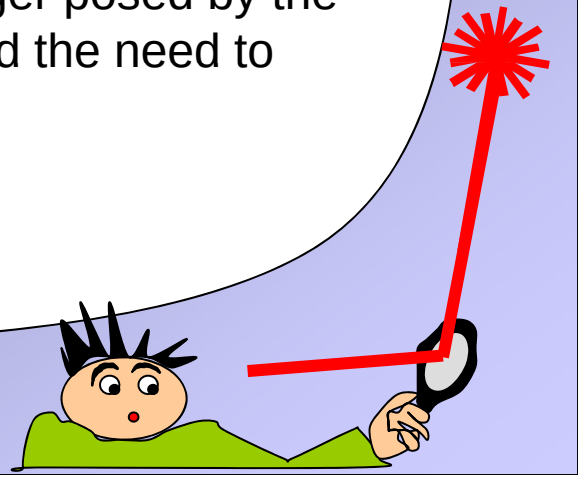
Practical laser safety in a university lab setting

Discussions during laser alignment exercises

Alignment exercise #1

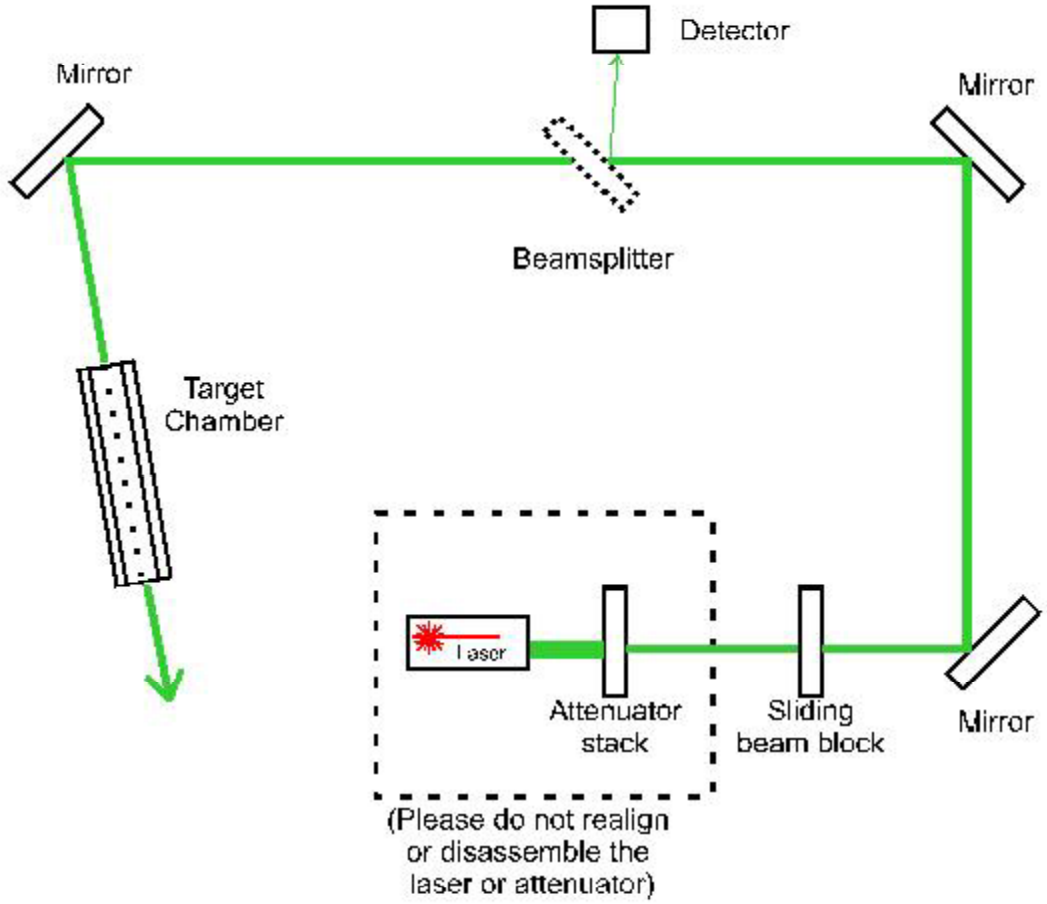
- When inserting the polarizing beamsplitter (PBS), the specular reflections off the front and back surfaces should be identified and blocked

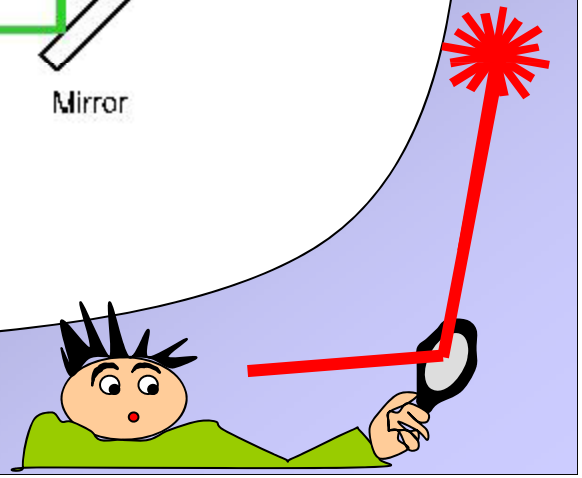
- When demonstrating how the PBS serves as a variable attenuator, students should identify the danger posed by the rotating dump beam and the need to mitigate it



Practical laser safety in a university lab setting

Laser alignment exercise #2





Practical laser safety in a university lab setting

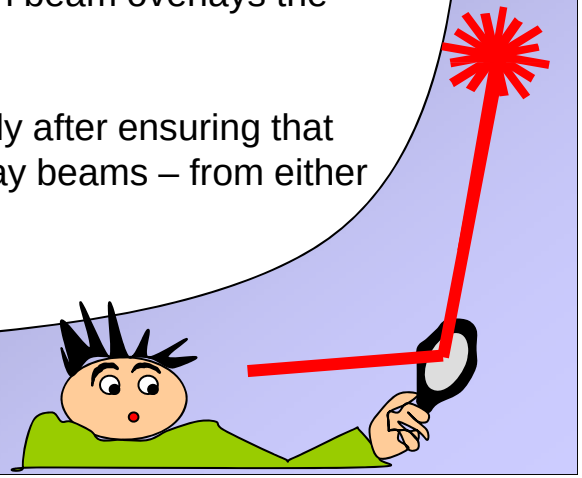
Discussions during laser alignment exercises

- The “target chamber” is locked to the laser table at an odd angle, mimicking the common problem of needing to find a location along the axis of the chamber to place a mirror. This geometry creates an opportunity to discuss alternate strategies to sighting down a laser beam line

- Alternate strategies discussed after students have come up with their solution:

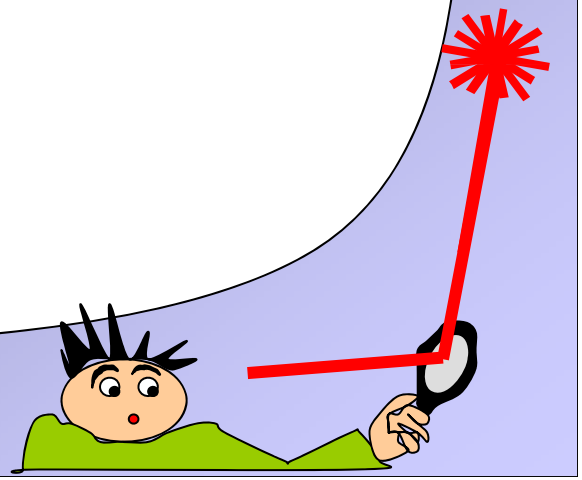
Use of an eye-safe laser or flashlight as an alignment tool, use of a string or mounts as sighting tools, use of a mirror on the chamber input flange to check if the return beam overlays the input beam, etc

Included in discussion is the option of sighting down the beam line, but only after ensuring that multiple layers of protection are in place to ensure that no main or stray beams – from either setup – could pose a danger



Practical laser safety in a university lab setting

Does each person have the means to stay safe and are they free from pressure to cut safety corners?

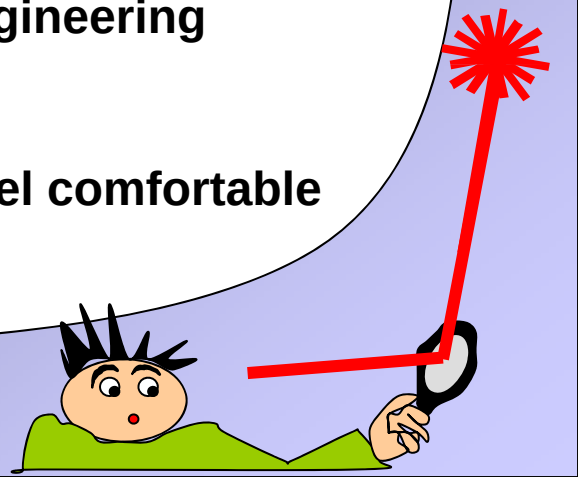


Practical laser safety in a university lab setting

Summary:

You don't work in a national lab environment, so you don't have to adhere to many of the stringent controls used in that environment, but does your lab exhibit some bare minimum necessities for a safe work environment?

- **Ensure that no bystanders/outsiders are endangered by your laser lab**
- **Know what type of protection is required to make yourself safe in your lab: eyewear, procedures, engineering controls**
- **Create an environment where workers feel comfortable taking the appropriate safety measures**



Practical laser safety in a university lab setting

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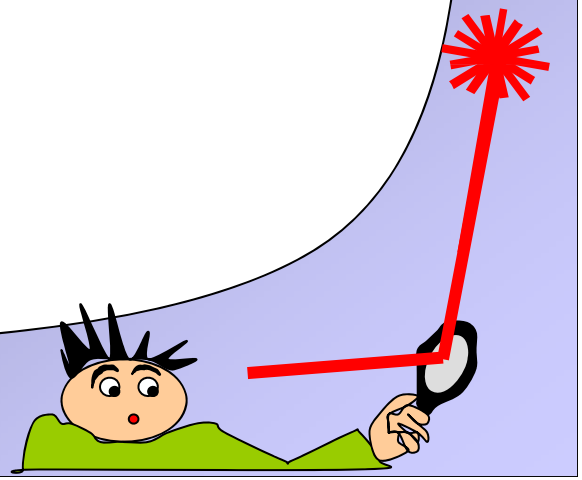
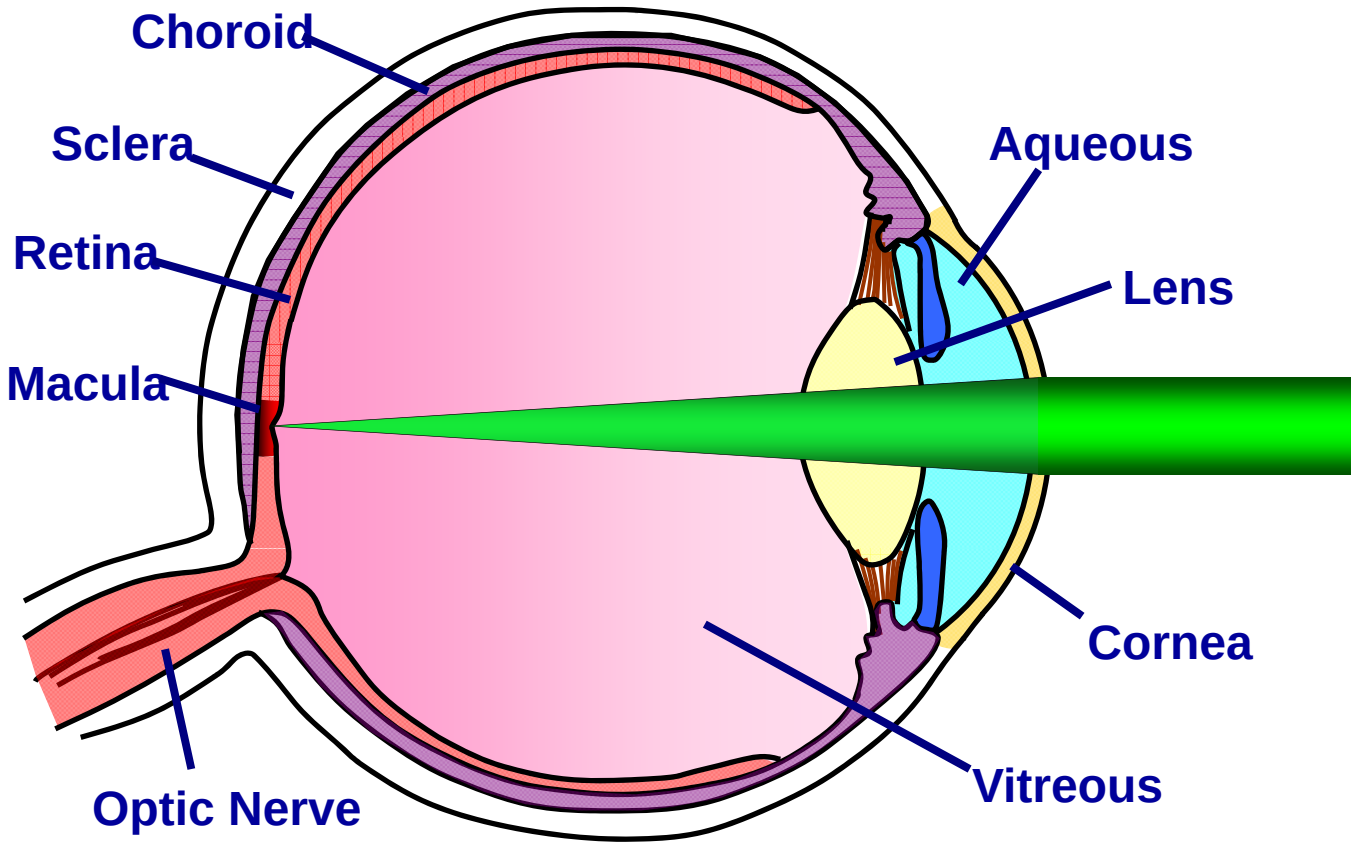


Practical laser safety in a university lab setting



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