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Title: Practical laser safety in a university lab setting

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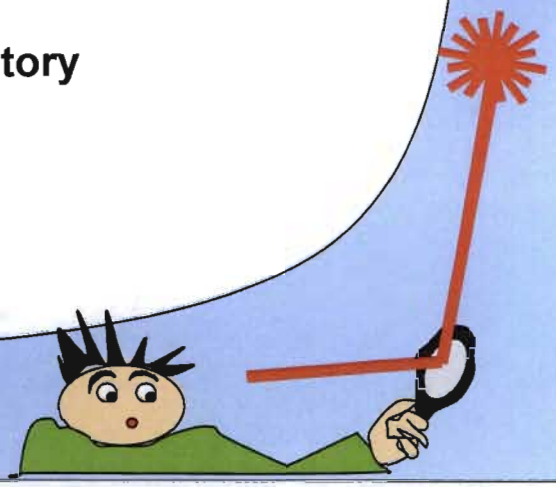
Form 836 (7/06)

Practical laser safety in a university lab setting

Dale Tupa, Physics Division, Los Alamos National Laboratory
Laser operations and development for 32 years
ANSI-certified Laser Safety Officer for 23 years

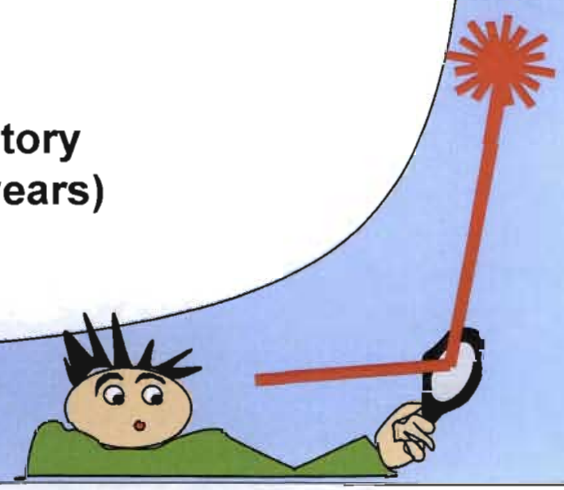


Practical laser safety in a university lab setting

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.

Dale Tupa, Physics Division, Los Alamos National Laboratory
(also ANSI-certified Laser Safety Officer for 23 years)

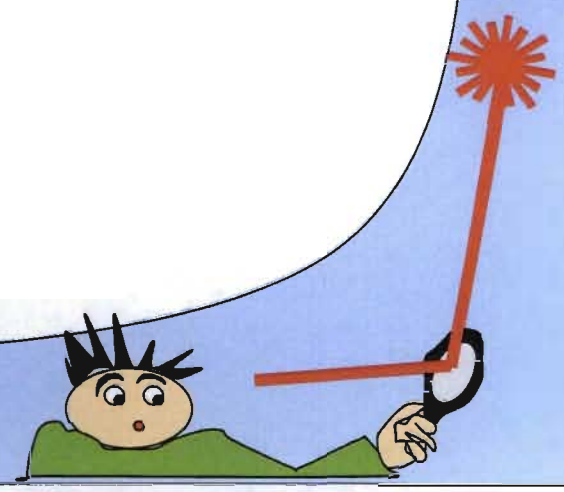


Practical laser safety in a university lab setting

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

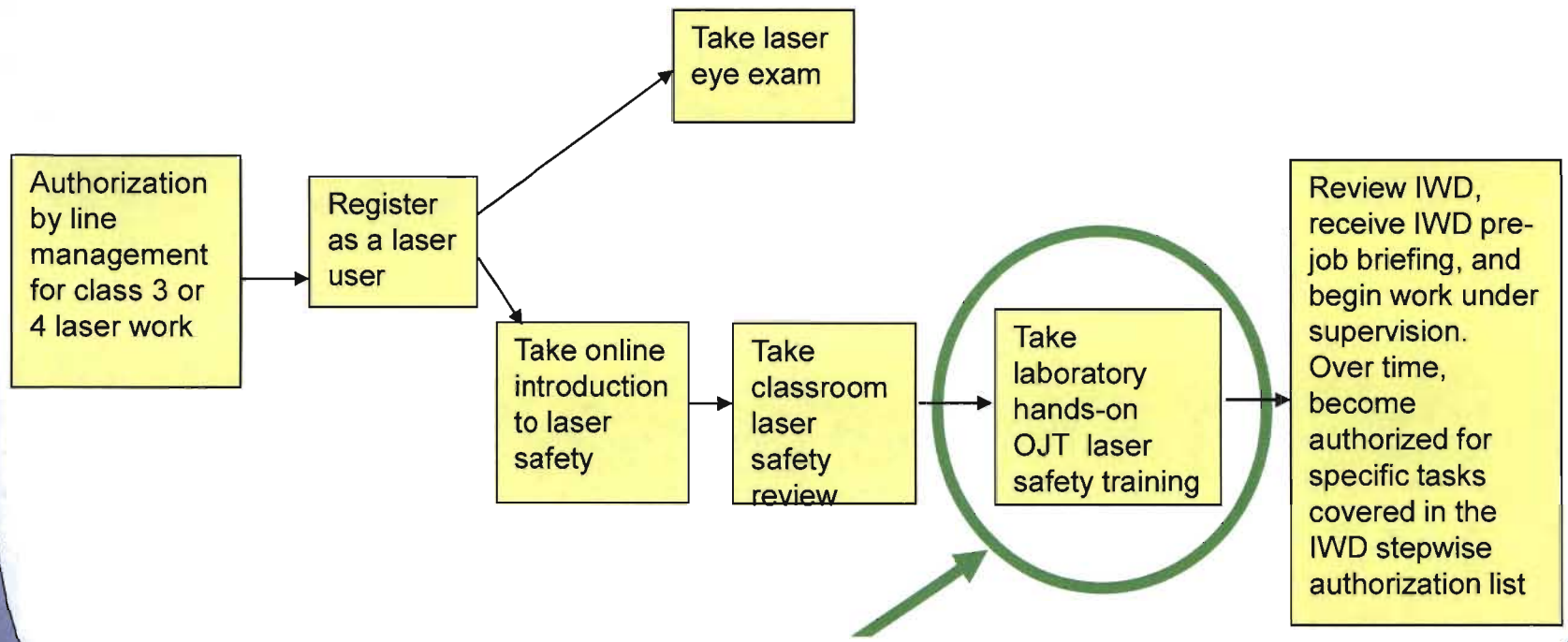
Laser-Professionals provides laser safety training and consultation services.

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



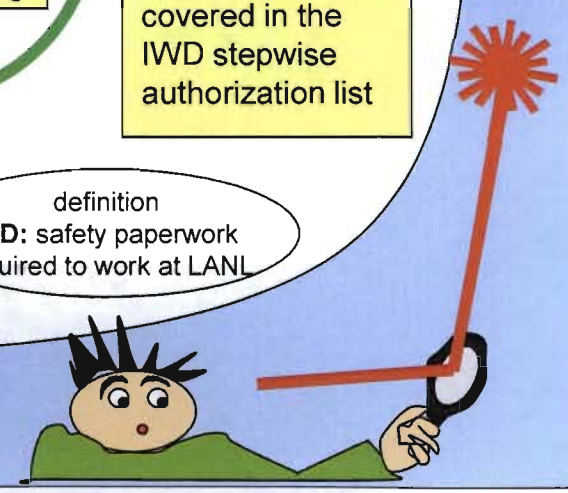
Practical laser safety in a university lab setting

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

Student preparation for the class: discussions with their supervisors

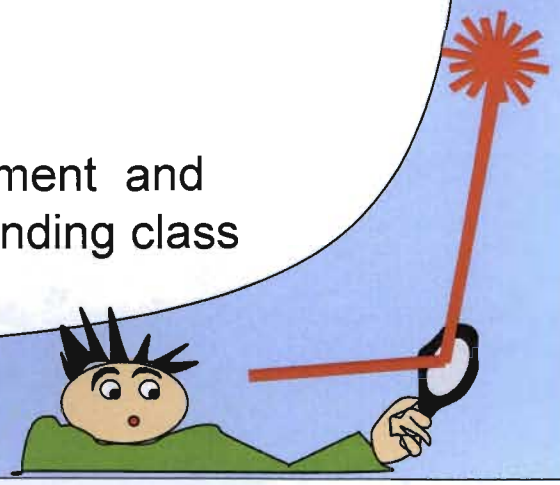
1. Students are asked to locate copies of the laser hazard analyses for the labs in which they will be working so they can learn how to interpret this documentation

2. Students are required to have discussions with their supervisors to identify special hazards that may exist in their labs.

   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

3. Students are given a list of guidelines for laser alignment and case histories of laser accidents to read before attending class

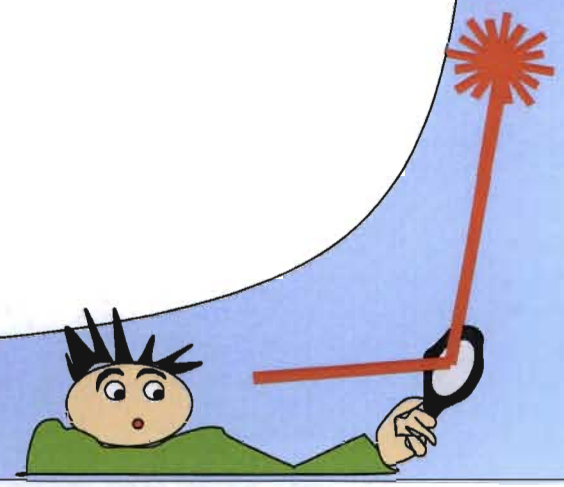


Practical laser safety in a university lab setting

Introduction and motivation

The goal of the class is to enable new laser users to:

A. identify hazardous situations in their labs and have a strategy to mitigate those hazards
B. be able to maintain a safety envelope while aligning elements or introducing new elements in a laser beam
C. leave the area safe when they are finished



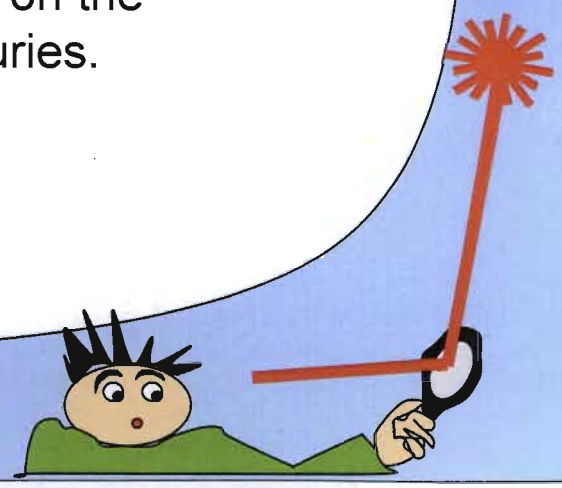
Practical laser safety in a university lab setting

Special discussion on the use of safety eyewear

It is stressed that 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.

Refer to laser accident case histories for discussion on the importance of laser safety eyewear in preventing injuries.



Practical laser safety in a university lab setting

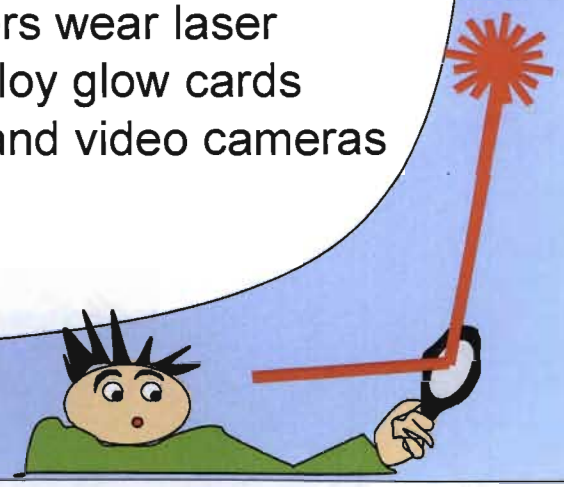
Lasers for demonstrations and hand-on exercises

Use 532 nm modules or laser pointers adapted to 1" mirror mounts

Neutral density filters are affixed in front of lasers to reduce the laser classification to class 2 or less

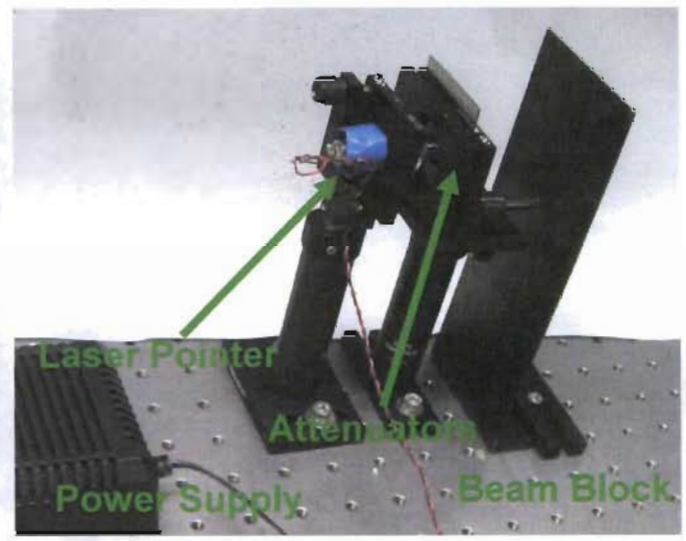
For demonstrations, this produces a beam easily visible to illustrate the points in question

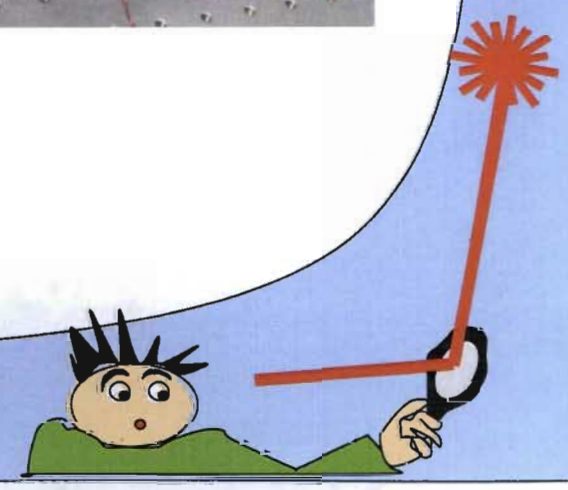
For exercises, inexperienced laser users have an easily visible beam to practice alignment procedures as if they have a visible cw laser whose power can be reduced for alignment. Experienced users wear laser goggles for argon-ion or doubled YAG lasers, and employ glow cards (fluorescent markers on a stick-um), ir beam viewers, and video cameras while aligning their beam and performing their sweeps



Practical laser safety in a university lab setting

Lasers for demonstrations and hand-on exercises





Practical laser safety in a university lab setting

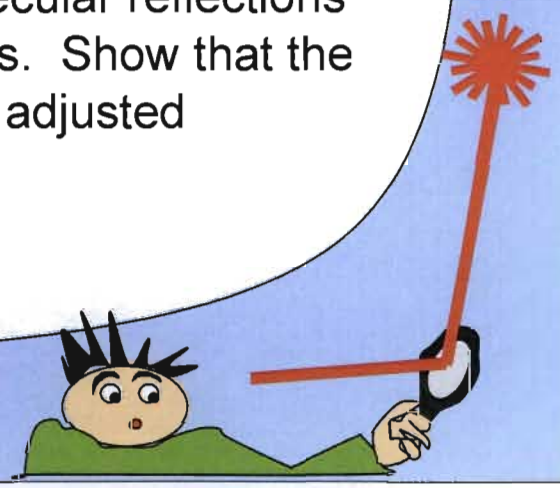
Laser alignment demonstrations

1. Place and align a mirror in the laser beam, demonstrating proper alignment techniques

2. Place a clear window in the laser beam, demonstrating the (possibly dangerous) specular reflections that result

3. Place a wedged window in the beam, demonstrating that multiple specular reflections result and that the main beam can be deflected

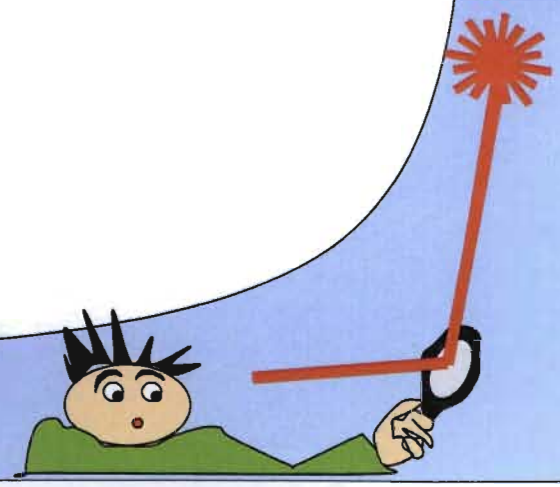
4. Place a lens in the beam, demonstrating that the specular reflections point in different directions and may have focal points. Show that the transmitted beam may wander around as the lens is adjusted



Practical laser safety in a university lab setting

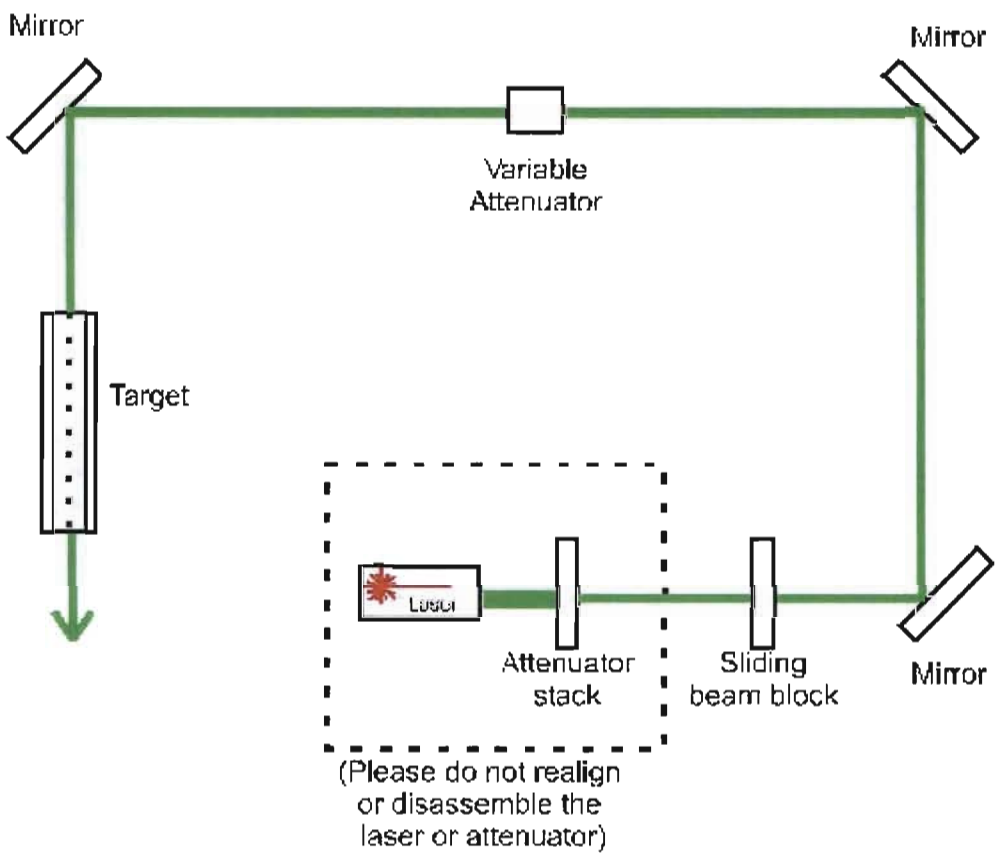
Laser alignment demonstrations

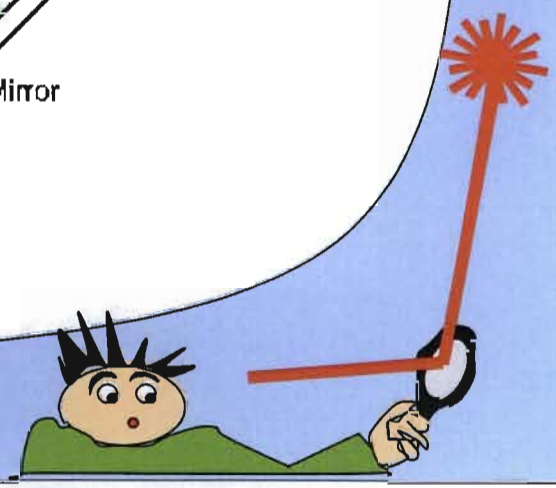
The demonstrations are summarized by pointing out that it is impractical to have a different alignment technique for every kind of optical element, and besides their behavior can be unpredictable. Rather, have an alignment technique that safely confines the main beam and all specular reflections, then perform a mini-sweep to locate all beams before proceeding to the next optic. Also, the demonstrations illustrate that it is important to have back-up controls such as eyewear when personnel can be exposed to laser beams



Practical laser safety in a university lab setting

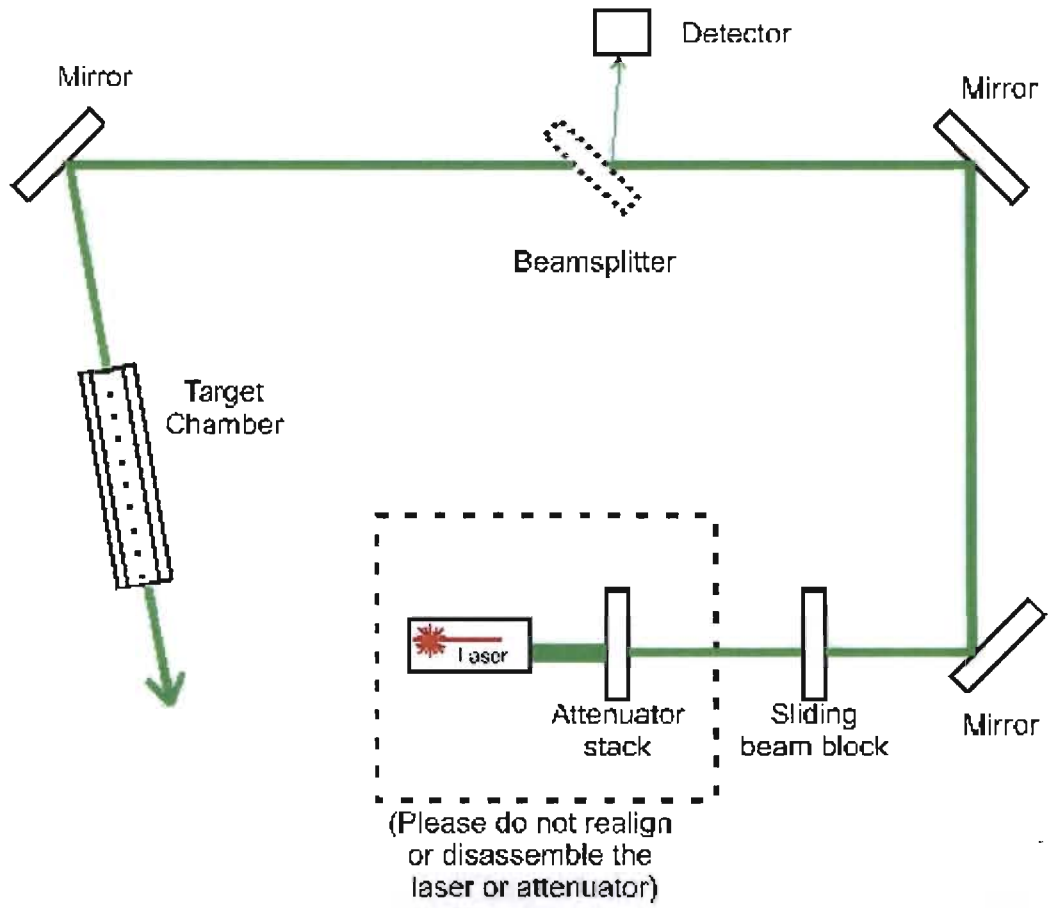
Laser alignment exercise #1

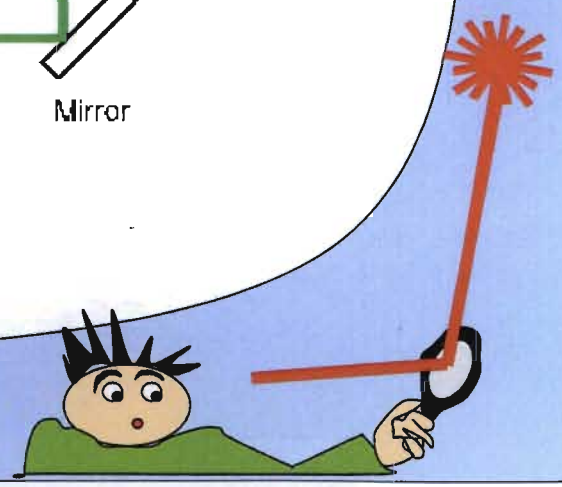




Practical laser safety in a university lab setting

Laser alignment exercise #2



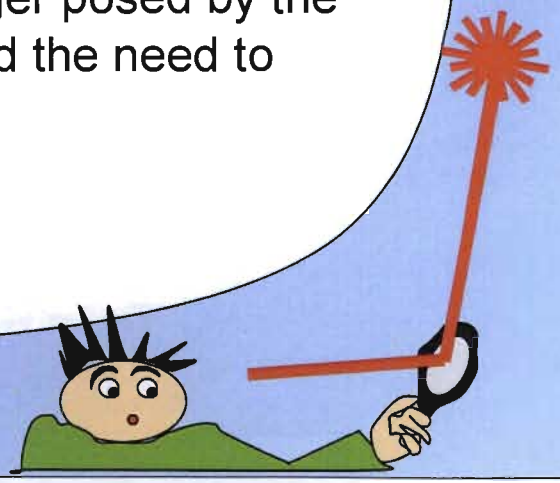


Practical laser safety in a university lab setting

Discussions during laser alignment exercises

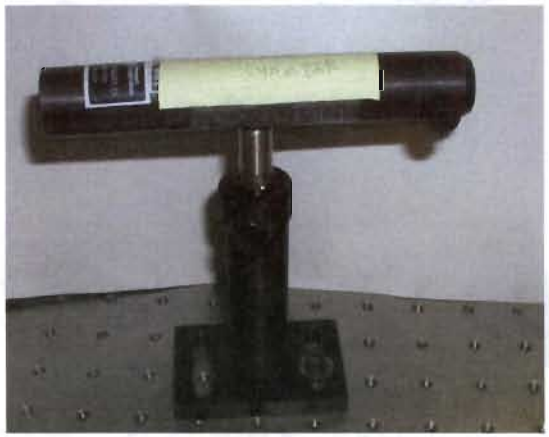
Alignment exercise #1

- 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

Discussions during laser alignment exercises

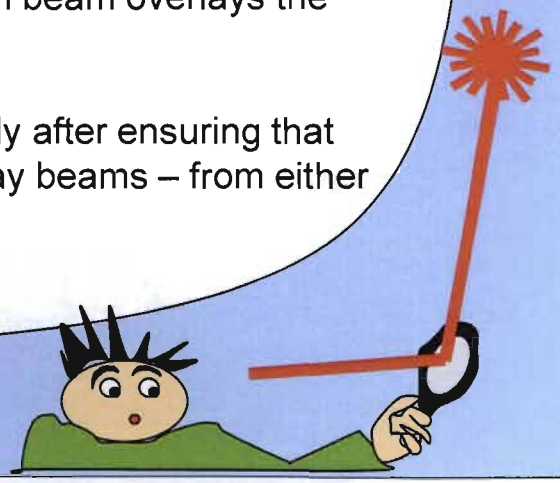


- The "target chamber" is locked to the laser table at an odd angle, mimicking the common problem of needing to find a location along the axis of the chamber to place a mirror. This geometry creates an opportunity to discuss alternate strategies to sighting down a laser beam line

- 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

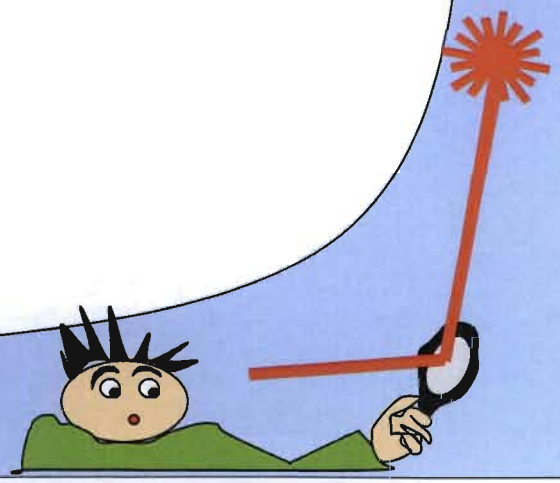


Practical laser safety in a university lab setting

Discussions after alignment exercises

If one group of students is ahead of the other when nearing the end of the exercises, that group installs table guards and guards between the two setups, and their setup is used to demonstrate the process of sweeping for stray beams before leaving a lab.

Examples of recent laser accidents are discussed. Students are asked for ways to prevent each accident, demonstrating that each one is a failure of multiple controls, and that employing multiple controls is a key to maintaining a safety envelope in the lab.



Practical laser safety in a university lab setting

Observations from five dry-run classes:

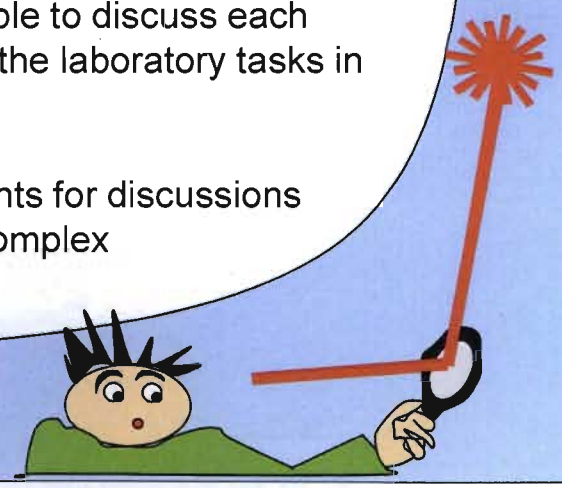
Students for the practice classes ranged from very experienced to high school students prepared only by the online training. The range of abilities enhanced the experience. Inexperienced students witnessed that the experienced students could complete a task of similar complexity in the same amount of time when wearing goggles

It seemed that it would be very difficult to provide a good learning opportunity if there were more than 4 students per class

Although the exercises look very easy, almost all students felt that they were quite challenged and would not have benefited greatly by a more complicated task. The exercises were greatly streamlined by ensuring in advance that all optical components were already of equal height and mirrors set for horizontal reflections, eliminating alignment steps that were not of instructional value

Preparation by students ahead of time was essential. It was not possible to discuss each important point in the guidelines for laser alignment and complete the laboratory tasks in four hours

It would be worthwhile to compile a better listing of recent laser accidents for discussions rather than simply using a listing of recent accidents in the DOE complex



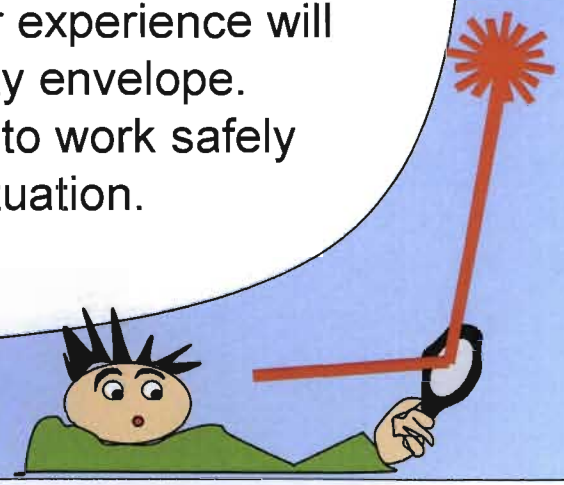
Practical laser safety in a university lab setting

Observations from Hands-On Alignment class:

1. We have designed a 4-hour hands-on laser alignment OJT class as part of a comprehensive training program for new laser users at Los Alamos National Lab. We have operated 5 practice classes with students of a variety of experience to refine the contents of the class

2. With input from training experts to refine class handouts and instructor materials, and to formulate a course outline, the pilot class will be ready to roll

3. We believe this class will significantly improve awareness of safe procedures for laser labs. New employees with laser experience will be given specific expectations for maintaining a safety envelope. People new to laser work will be equipped with skills to work safely and identify if they find themselves in a hazardous situation.

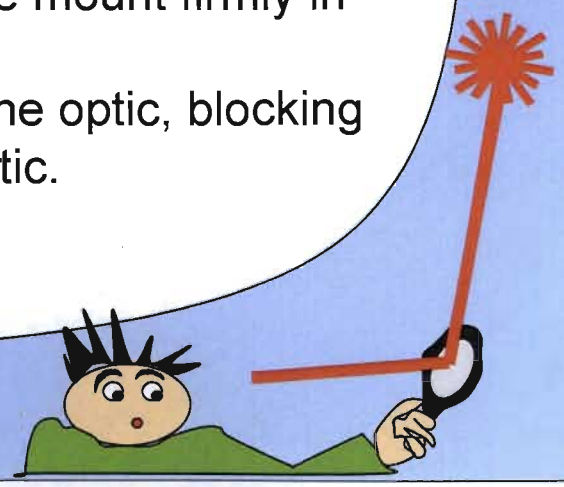


Practical laser safety in a university lab setting

Laser alignment demonstrations

Basic alignment procedure:

1. Block laser beam
2. Place optic in approximate location
3. Place beam block to stop the main beam if it misses the optic
4. Place beam block to stop the main beam if it hits the optic, whether the optic is properly aligned or not
5. Place beam block to catch other specular reflections
6. Hold a portable block or card in the beam path, unblock the laser beam, and track the beam as it encounters and passes the new optic
7. After ensuring that all beams are terminated, affix the mount firmly in place and fine-tune its position and pointing
8. Perform a mini-sweep for specular reflections from the optic, blocking them as necessary before proceeding to the next optic.



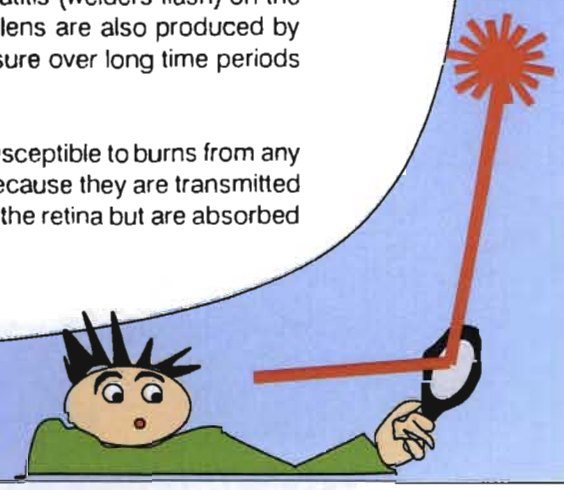
Practical laser safety in a university lab setting

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.



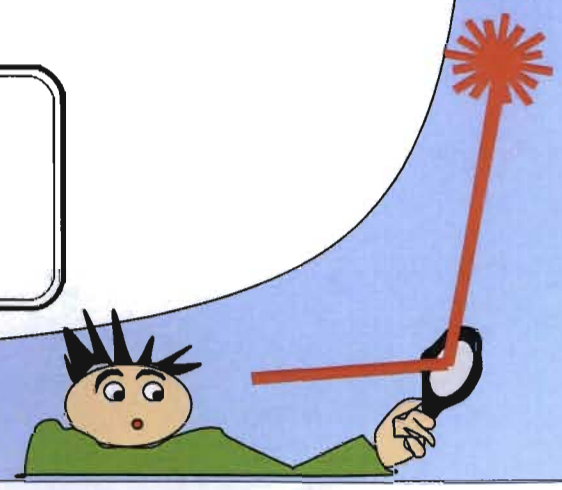
Practical laser safety in a university lab setting

LASER EFFECTS

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

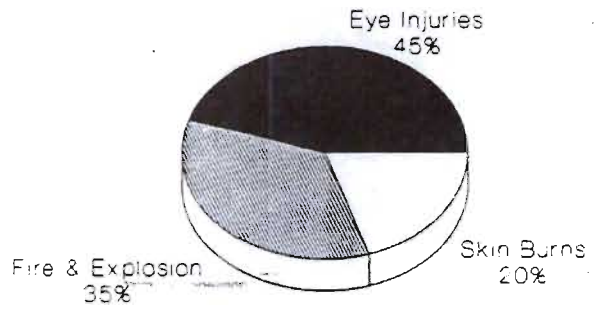
PHOTOCHEMICAL:
- Caused by chemical reactions within body tissue after absortion of laser energy.
- Only with wavelengths less than .550 μm.
- Exposure duration greater than 10 seconds.

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



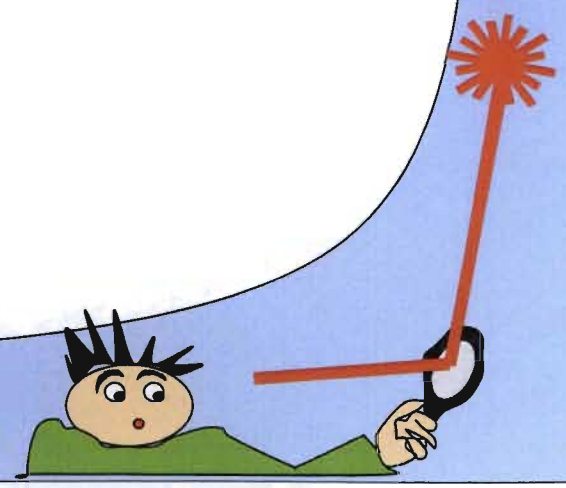
Practical laser safety in a university lab setting

Laser Beam Accidents
Type of Accident



Accident Conditions
Laser Beam Hazards

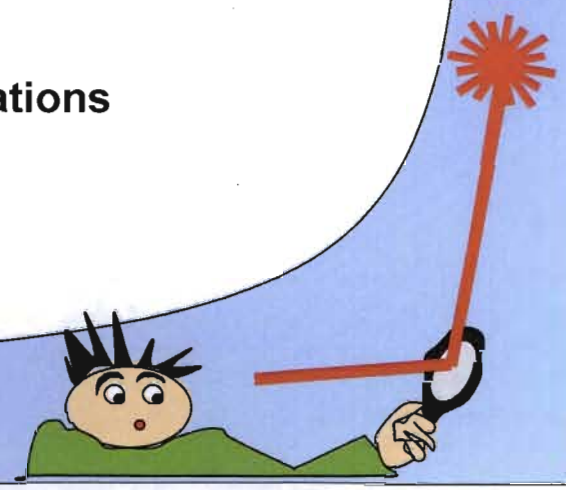
- Alignment Exposure
- Misaligned Optics
- Intentional Exposure
- Equipment Unfamiliarity
- No Eye Protection



CAUSES OF LASER ACCIDENTS

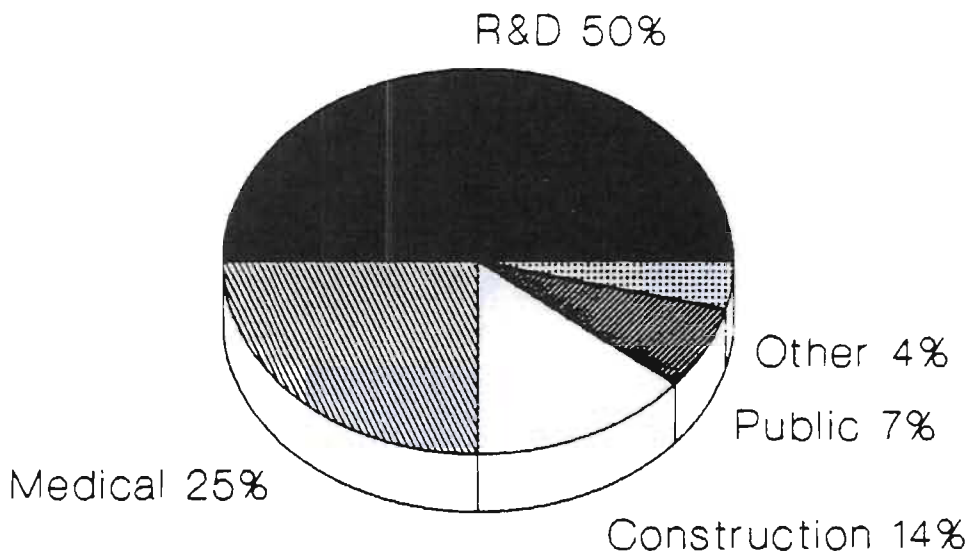
Studies of laser accidents have shown that there are usually several contributing factors. The following are common causes of laser injuries:

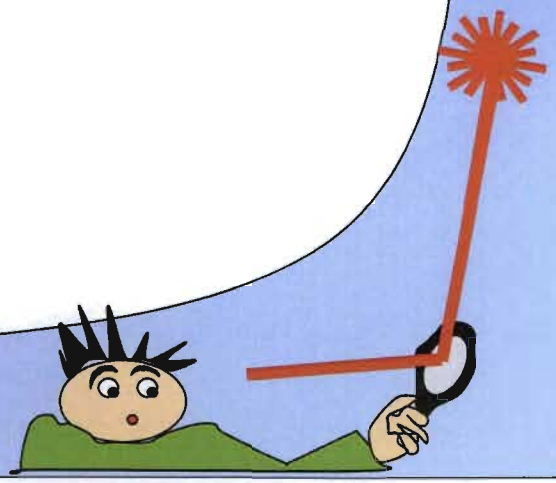
- Inadequate training of laser personnel
- Alignment performed without adequate procedures
- Failure to block beams or stray reflections
- Failure to wear eye protection in hazardous situations
- Failure to follow approved standard operating procedures or safe work practices



Practical laser safety in a university lab setting

Laser Accidents
Where Occurring





LASER SKIN INJURIES

THERMAL SKIN INJURIES

Surface burns from high power beams

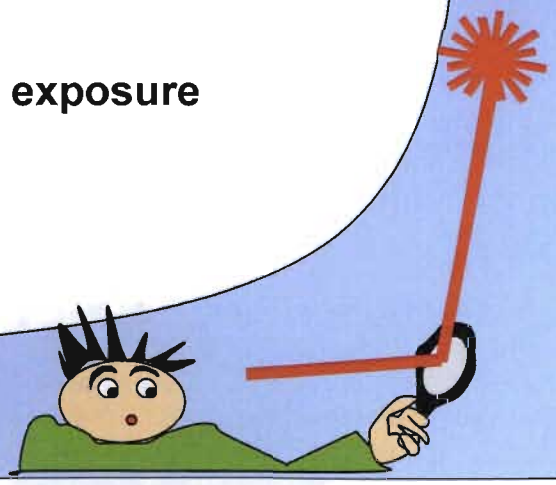
Deeper burn penetration at 1 μm wavelength

Tissue vaporization by focused beams

PHOTOCHEMICAL SKIN INJURIES

Sunburn from scattered UV

Possibility of skin cancer from long term UV exposure



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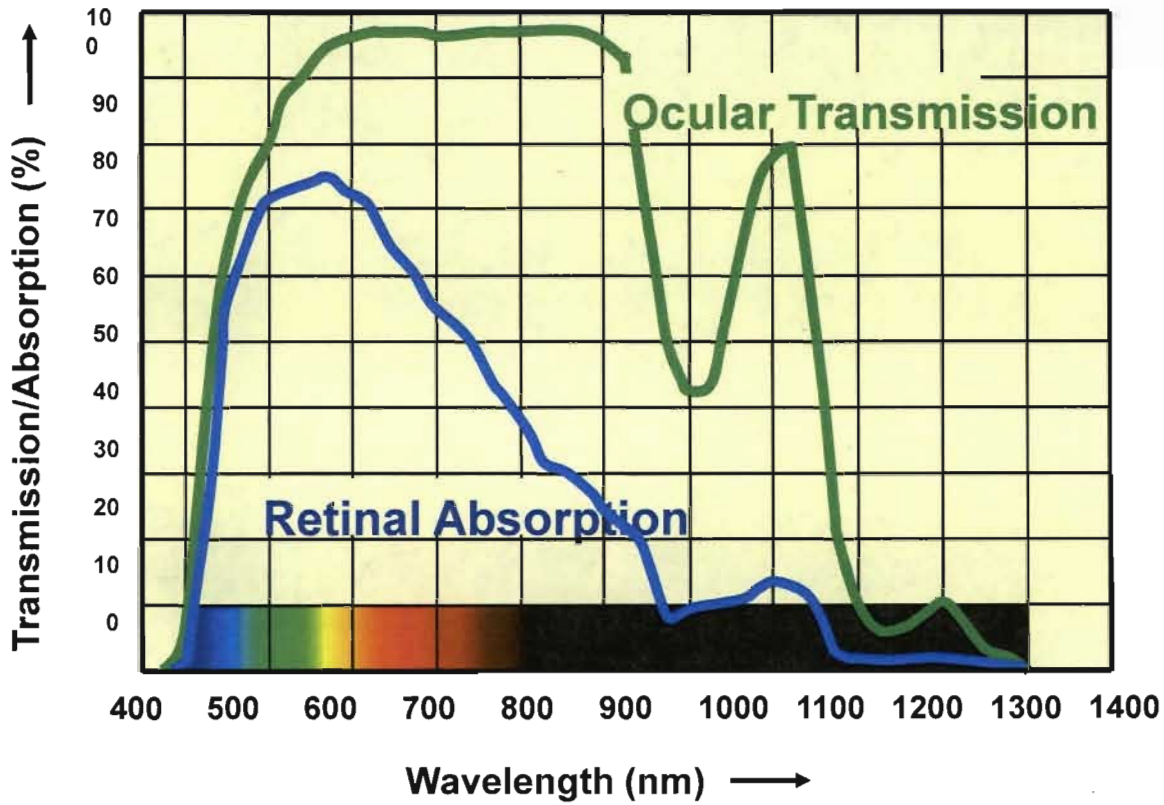

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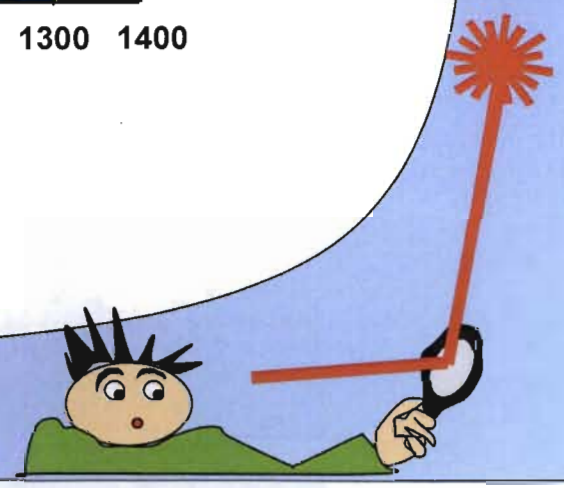

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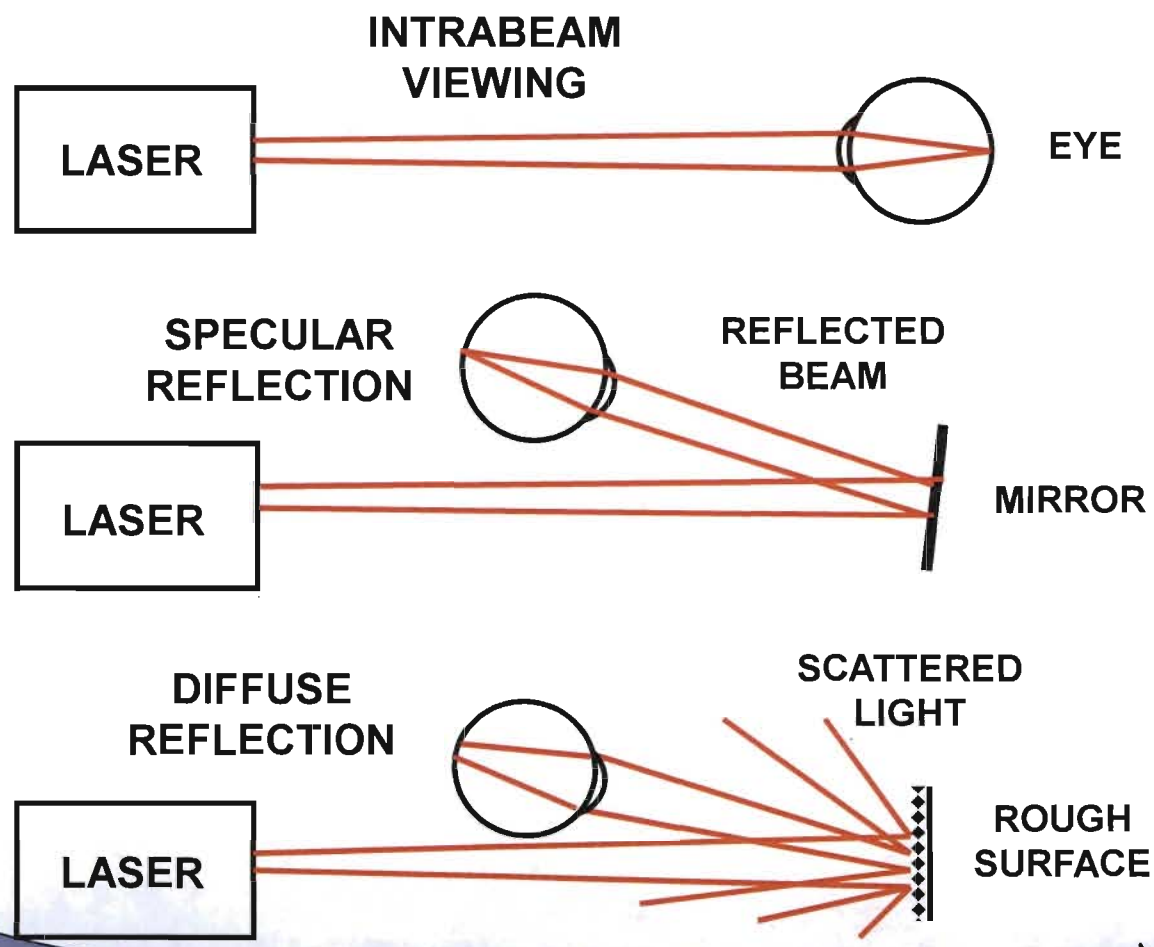

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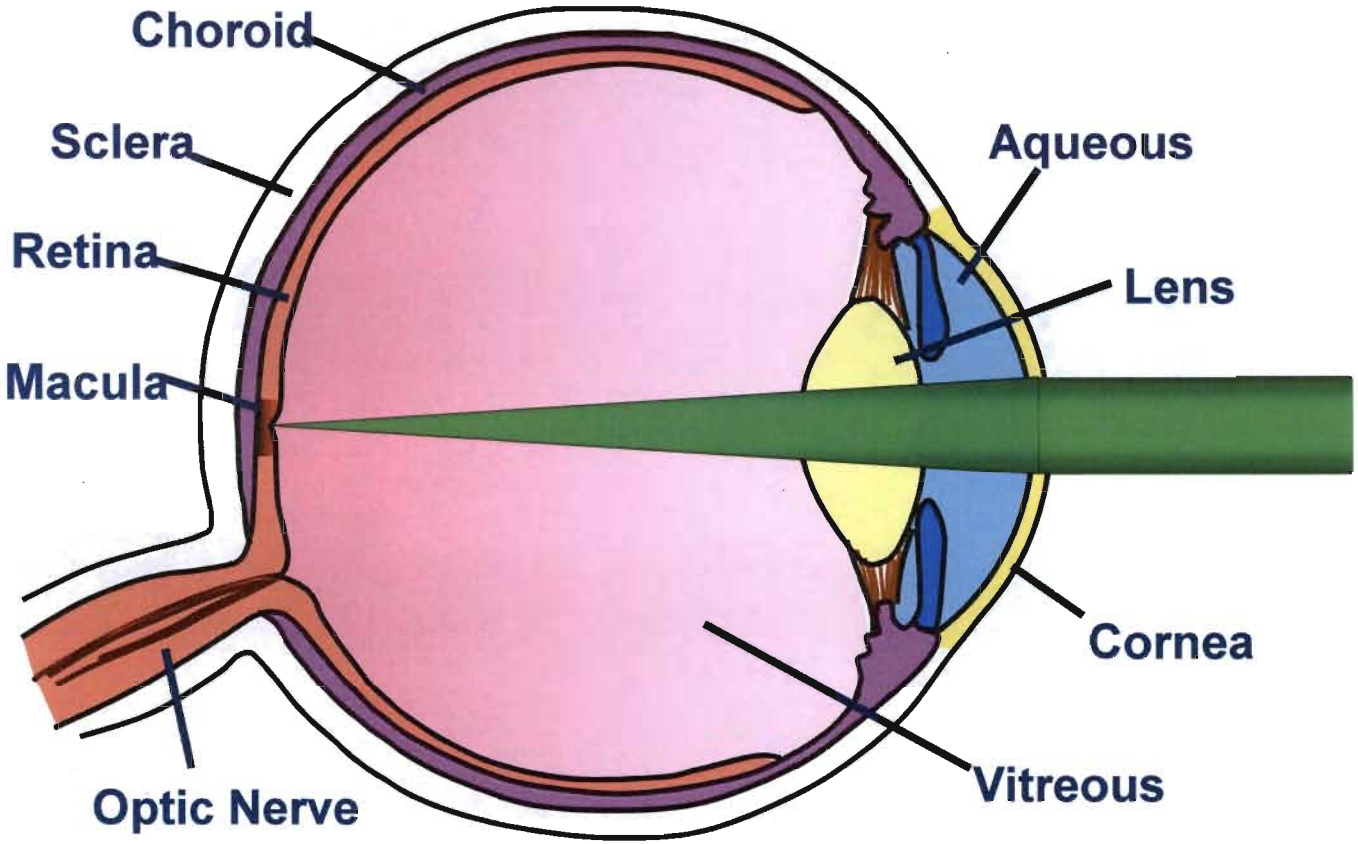

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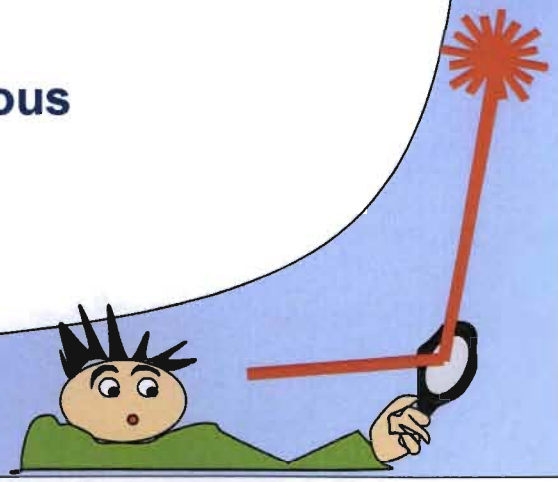


CHARACTERISTICS OF LASERS AND THEIR EFFECTS ON LASER HAZARDS

Spectral characteristic – Wavelength

In general, shorter wavelengths are more hazardous in any spectral region, but Near Infrared lasers are the most hazardous because they are invisible retinal hazards.

Temporal characteristic – Pulse Duration

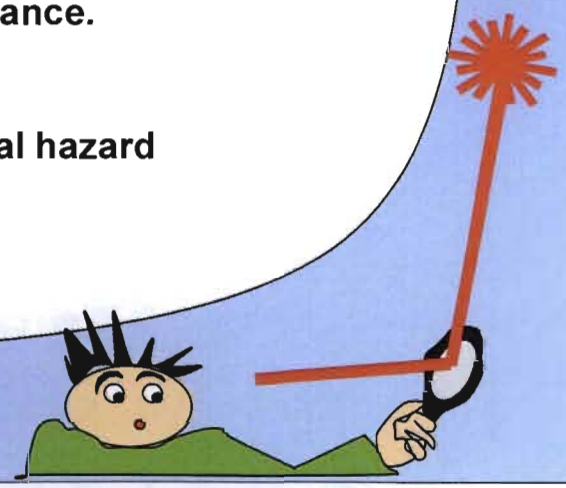
In general, pulsed lasers are more hazardous than CW lasers. The shorter the pulse duration, the higher the peak power and the greater the hazard.

Spatial characteristic – Beam Divergence

Low beam divergence results in a large intrabeam hazard distance.

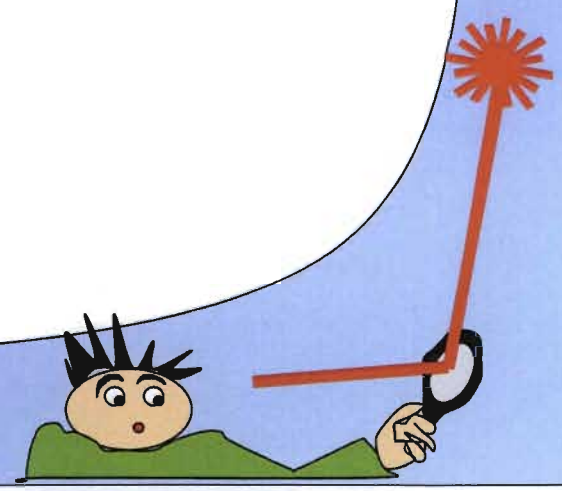
Focusing characteristic

High retinal irradiance of focused beam creates extreme retinal hazard for visible and near infrared lasers.



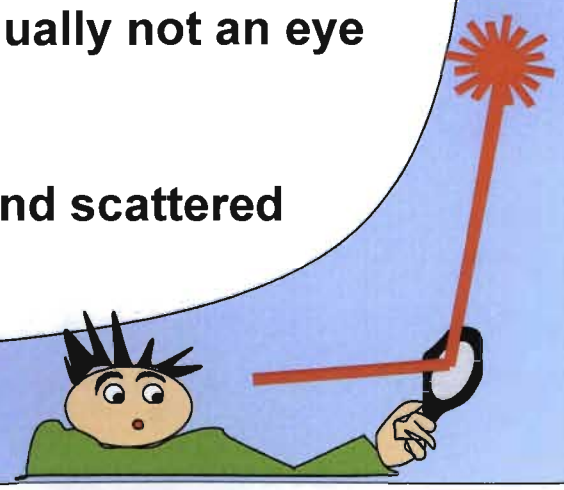
NON-BEAM HAZARDS

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



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**

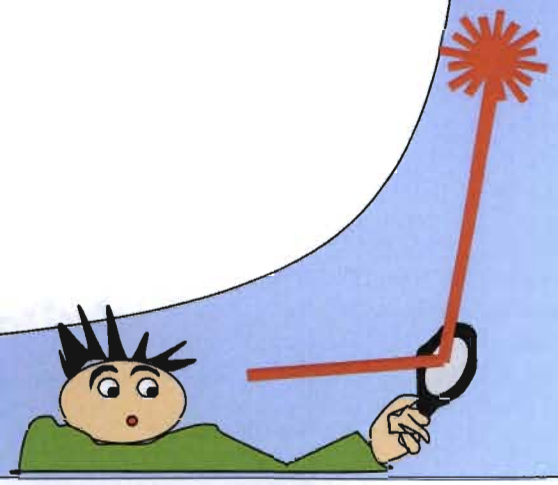


LASER SAFETY STANDARDS

The Federal Laser Product Performance Standard (FLPPS) of the Center for Devices and Radiological Health (CDRH)
This is federal law and applies to the manufacture of lasers.

The American National Standard for Safe Use of Lasers (ANSI Z136.1)
This is a VOLUNTARY Standard that applies to the use of lasers.
It's "recognized by":The Occupational Safety and Health Administration (OSHA)

IEC 60825 International Standard



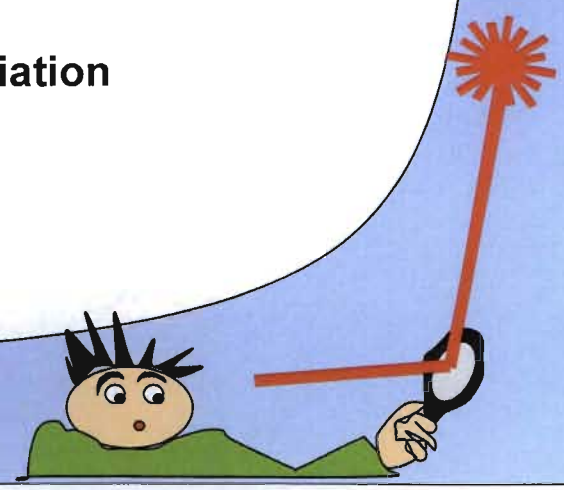
LASER HAZARD EVALUATION

FACTORS IN HAZARD EVALUATION

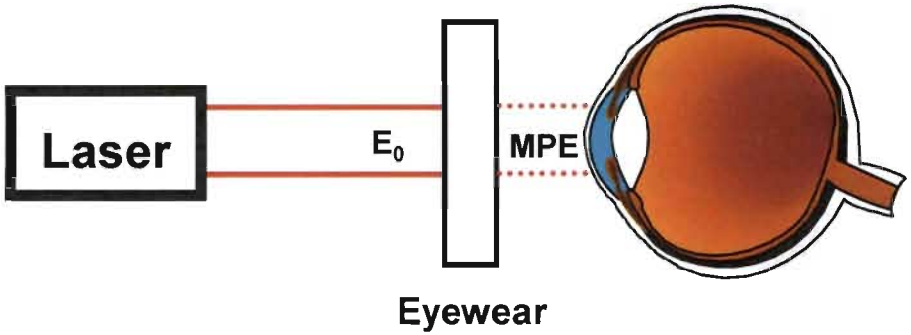
The laser or laser system's capability of injuring personnel
(Hazard Analysis Calculations)

The environment in which the laser is used

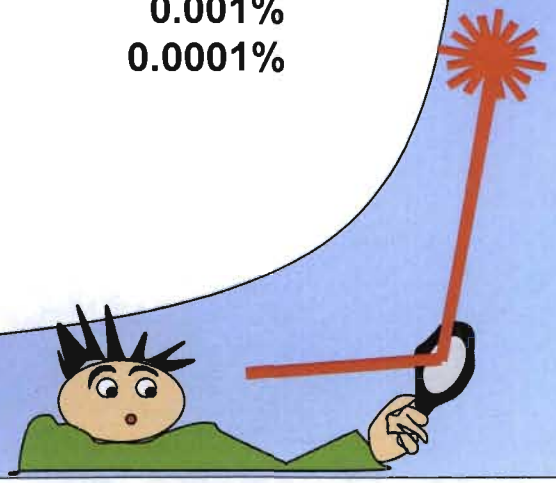
The personnel who may use or be exposed to laser radiation



OPTICAL DENSITY OF LASER SAFETY EYEWEAR



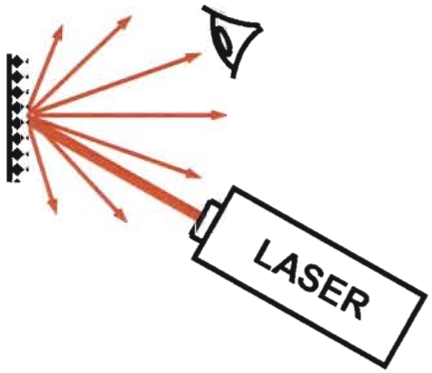
OD	% Transmission
0	100%
1	10%
2	1%
3	0.1%
4	0.01%
5	0.001%
6	0.0001%



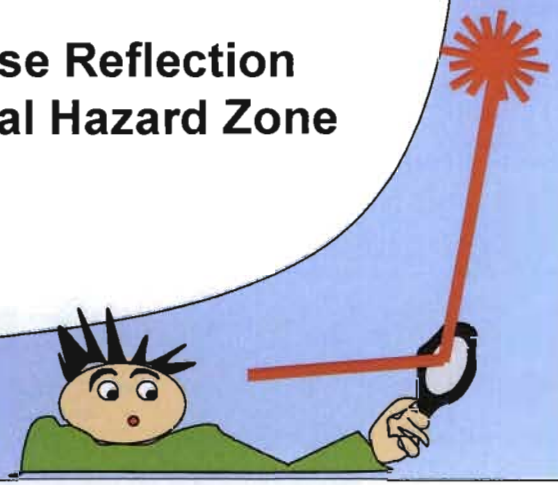
NOMINAL HAZARD ZONE

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

Intrabeam Nominal Hazard Zone



Diffuse Reflection Nominal Hazard Zone



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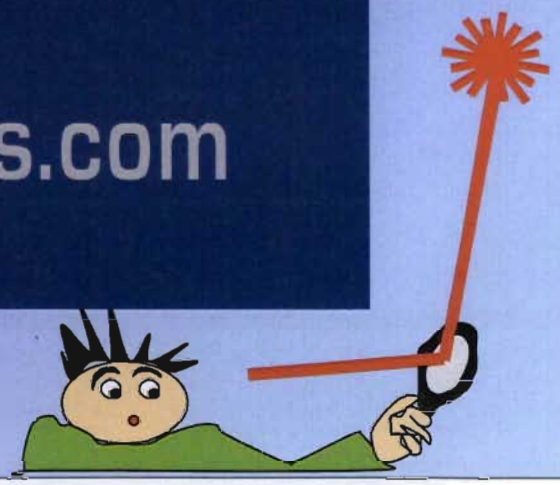
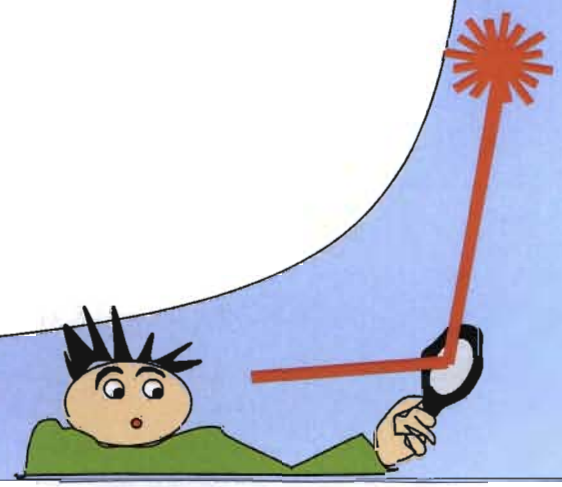


Practical laser safety in a university lab setting

Summary:

Ensure that no bystanders are endangered in 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