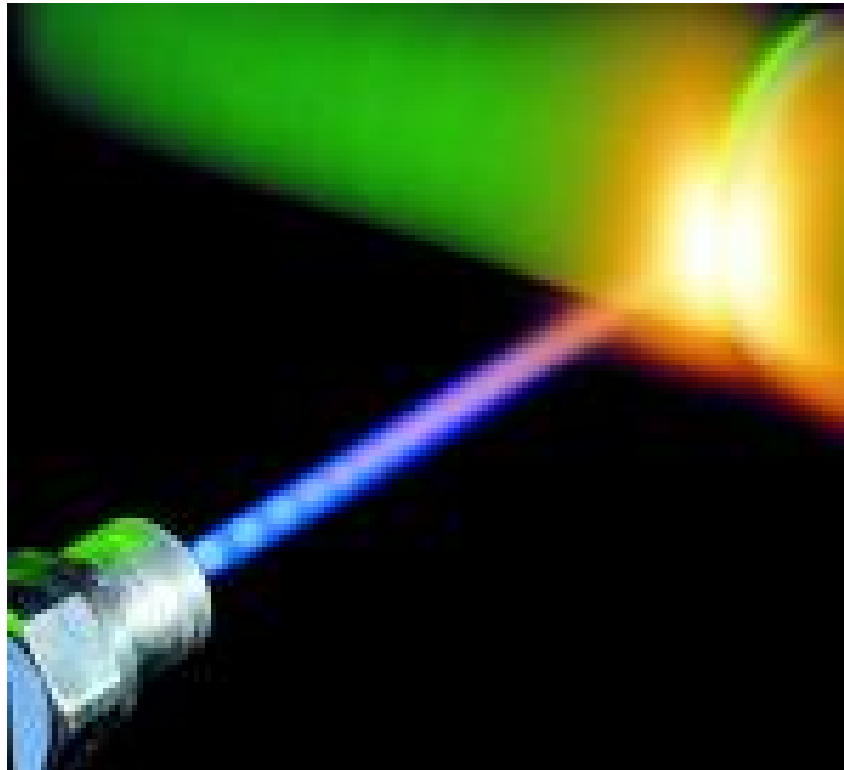


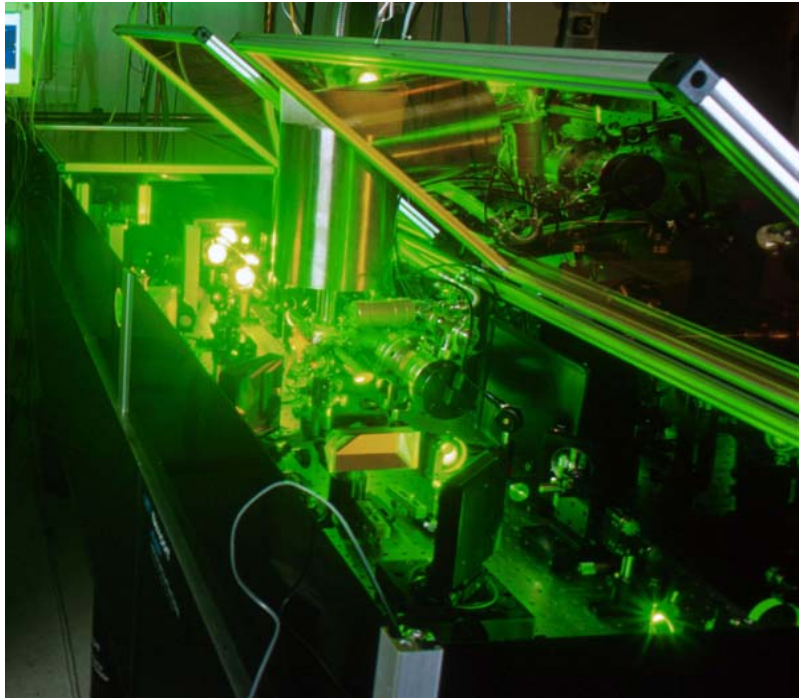


Laser Safety Information

University of Manitoba draft May 1, 2009



So you plan to use a laser at the University of Manitoba...



Then, there are some things you need to know about:

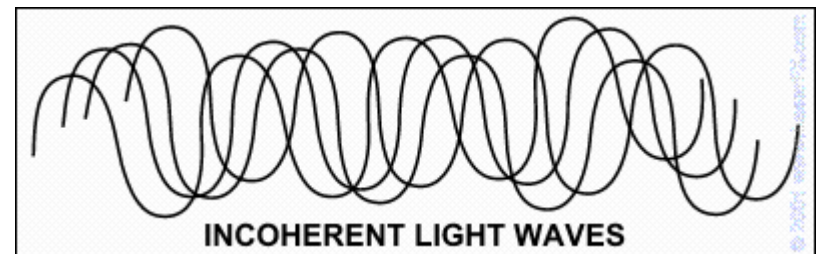
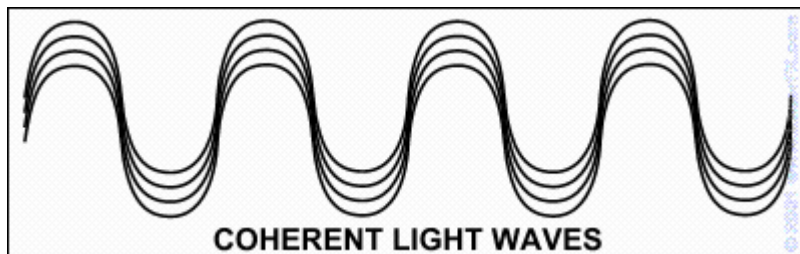
- ✓ Lasers hazards
- ✓ How to identify lasers in your work area
- ✓ How to work safely with lasers
- ✓ How to work safely around others



What is a Laser?

Laser: Acronym of Light Amplification by Stimulated Emission of Radiation. A device that produces radiant energy predominantly by stimulated emission. Laser radiation may be highly coherent temporally, or spatially, or both. **A laser can produce a very intense, very narrow beam of electromagnetic radiation, in the form of visible light, infrared or ultraviolet.**

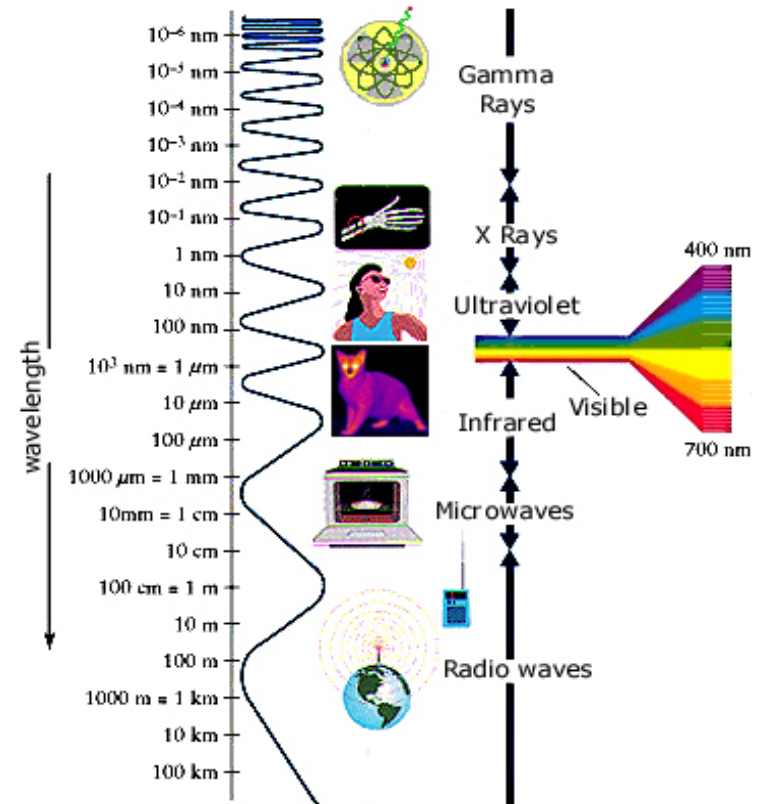
Coherent: A light beam is said to be coherent when the electric vector at any point in it is related to that at any other point by a definite continuous function.



What is Laser Radiation?

Collateral Radiation: Any electromagnetic radiation, except laser radiation emitted by a laser or laser system which is physically necessary for its operation.

Electromagnetic Radiation: The flow of energy consisting of orthogonally vibrating electric and magnetic fields lying transverse to the direction of propagation. X-ray, ultraviolet, visible, infrared and radio-waves occupy various portions of the electromagnetic spectrum and differ only in frequency, wavelength and photon energy.





What are common types of lasers?

Lasing media	Wavelength of laser radiation
Helium neon (HeNe)	633nm
Argon	488-514nm
Neodinium-YAG (Nd-Yag)	1063 (1330)nm
Carbon Dioxide (CO ₂)	10600nm

How are lasers labeled?



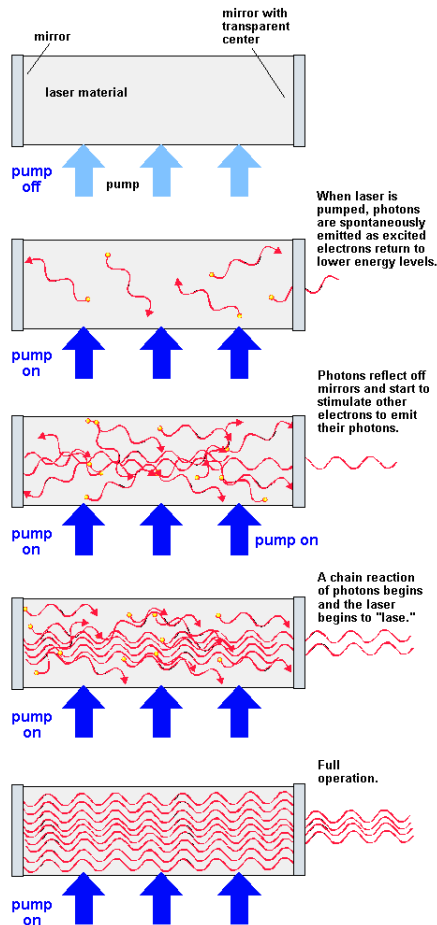
There are many ways a laser or laser system may be labeled depending on when and where it was made

Look for the following types of labels:



How does a laser work?

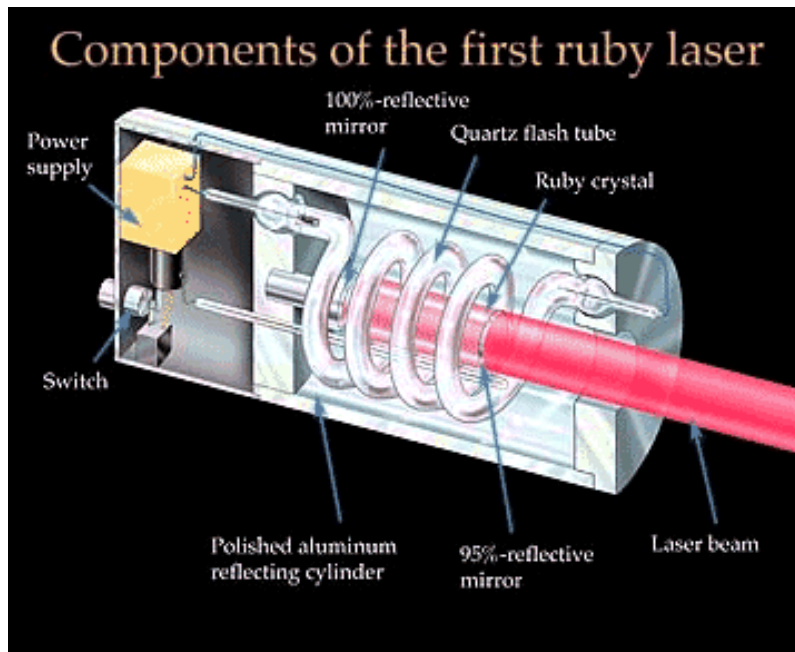
From Computer Desktop Encyclopedia
© 2001 The Computer Language Co. Inc.



The light (radiant energy) in the Optical Resonator Cavity is "bounced" back and forth between the two mirrors until enough energy is gained to pass through the semi reflective mirror.

Anatomy of a Laser

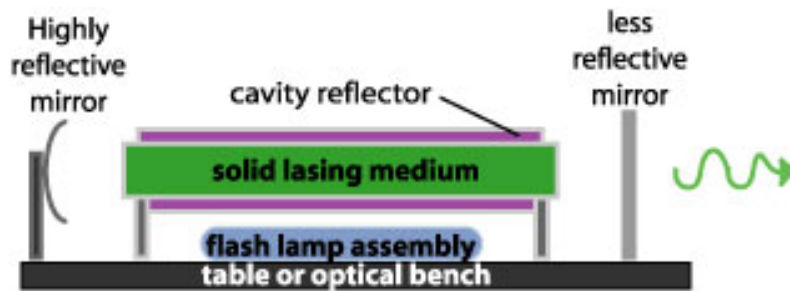
Example of a Ruby Laser



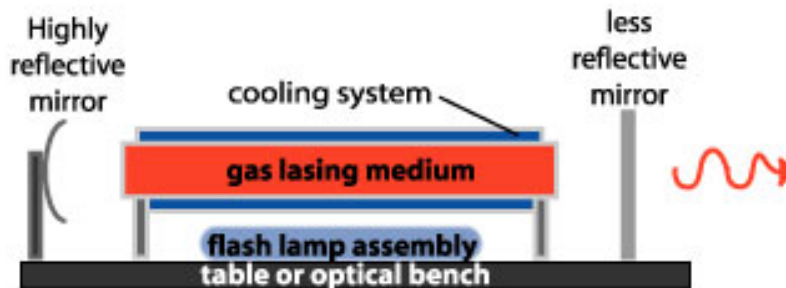
1. **Energy Source**
(optical, electrical or chemical)
eg. power supply & quartz flash tube
2. **Amplifying medium**
(solid, gas or liquid)
eg. Ruby crystal
3. **Optical resonator cavity**
eg. Polished aluminum reflecting cylinder and 100 & 95% reflective mirrors

Anatomy of a Laser

Example of diode or CO₂ lasers



Solid-state laser



CO₂ laser

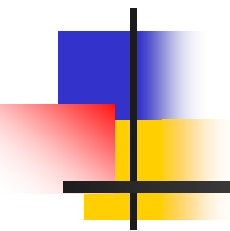
1. **Energy Source**
(optical, electrical or chemical)
eg. flash lamp assembly or another laser
2. **Amplifying medium**
(solid, gas or liquid)
eg. Diode (solid state lasing media) or CO₂ (gas lasing media)
3. **Optical resonator cavity**
eg. reflecting cylinder and highly reflective mirrors



What are the properties of Laser Radiation that make a laser useful?

- Low divergence (highly directional)
 - If a laser were aimed at the moon the spot on the moon would only be a few km wide (at a distance of 380 000km!)
- Very high brightness
 - 1mW HeNe laser appears 100 times brighter than the sun
- High power density
 - Focused < 1micron spot can evaporate metal and drill diamond
- Coherence and Monochromatic (single frequency) and short pulses (femtoseconds= 1millionth of a billionth of a second)
 - Can carry 10 000 times more information than microwaves
 - Can carry 1 billion time more information than radiowaves

The properties of laser radiation that make it useful also create a hazard to humans!



Lasers are evaluated in order to classify the level of hazard they create.



How is the laser hazard evaluated?

MPE – maximum permissible exposure The level of laser radiation to which a person may be exposed without expected hazardous effects or adverse biological changes in the eye or skin. The MPE is specific to each laser and is calculated from the wavelength, expected duration and other factors.

NHZ – nominal hazard zone The space in which the level of direct, reflected or scattered radiation during normal operations exceeds the applicable MPE. NHZ varies with the laser in use and the way it is being used.

LCA - laser controlled area The area where the occupancy and activity of those within is subject to control and supervision for the purpose of protection from Laser Hazards. To be safe the LCA must equal or exceed the NHZ.

Classifications of Low Hazard Lasers



- **Class 1** – do not under normal circumstances pose a hazard. Usually laser is embedded into a laser product and interlocked in a manner that the laser can not be powered unless the enclosure is intact.
- **Class 2** – low power visible lasers do not normally pose a hazard because of human bright-light aversion. The power level is $< 1\text{mW}$.
- **Class 3R (formerly Class 3a)** – are capable of exceeding the MPE, but still pose low risk for injury. The power level is $1\text{-}5\text{mW}$.



How can you protection yourself from low hazard lasers?

When working with or around Class 1, 2 and 3R Lasers:

- Avoid direct exposure of the eyes to the beam or the reflected beam
- Do not remove the housing or use a laser with a damaged enclosure – maintenance and servicing may only be performed by individuals trained in regards to laser safety
- Do not align the beam with the naked eye
- Avoid reflecting the beam

Classifications of Hazardous Lasers



- **Class 3B** – denotes laser that can produce a hazard if viewed directly. Normally will not produce a hazard from diffuse reflection from a matte target. The power level is 5-500mW for a continuous laser and $< 10\text{J}/\text{cm}^2$ for a 0.25 s pulsed laser.
- **Class 4** – denotes a laser that produce a hazard not only from direct or specular (mirror like) reflections, but may also produce hazardous diffuse reflections. May produce significant skin hazards and fire hazards in addition to the eye hazards. The power level is $> 500\text{mW}$ for a continuous laser and $> 10\text{J}/\text{cm}^2$ for a 0.25 s pulsed laser.



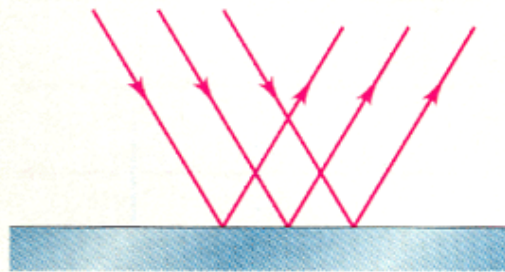
Never look directly into a laser beam!

Class 3B and 4 lasers may cause:

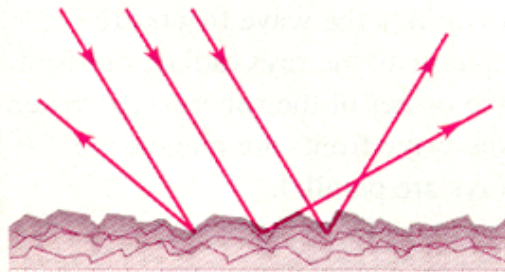
- Acute (immediate) effects such as burns/blindness. or
- Delayed (accumulative) effects such as cataracts or cancer!

All Lasers are potentially hazardous if misused!

Reflected laser beams from Class 3B or 4 lasers are hazardous!



(a) Specular reflection.



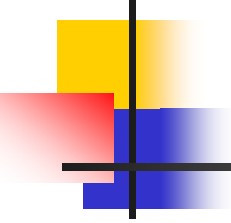
(b) Diffuse reflection.

Specular Reflection:

Mirror like reflection cause as much damage as intrabeam exposure. Specular reflections are dangerous because they do not cause beam divergence. **CO₂ lasers specularly reflected from visibly dull surfaces.**

Diffuse Reflection:

Change in the spatial distribution of a beam of radiation which it is reflected in many directions by a surface or medium.



Laser beam can harm human eyes because:

- Laser beam can be focused by the human eye to 25microns on retina
- Human eye can increase the laser power density by 100 000x
- Eye focuses both visible and invisible infrared radiation! (and you can't see infrared!)
- Single pulse of 0.5mJ can cause permanent retinal damage (blindness if central vision affected)

All Lasers are potentially hazardous if misused!



What types of eye injuries can happen from Class 3B and 4 lasers?

Corneal and/or retinal burns, retinal injury, and corneal opacities are possible.

Mechanisms of damage include thermal, photochemical and acoustic (pressure wave) effects.



Thermal effect on eye will vary with laser wavelength.

Visible or near infrared wavelengths impact the retina or macula lutea.

Wavelengths less than 400 nm produce photochemical effects, rather than thermal effects.

With the eye's optical gain (focussing), 1 mW/cm² to the eye will become 100 W/cm² when it reaches the retina.

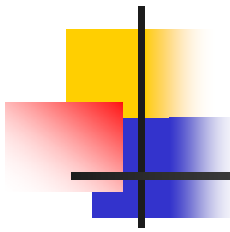
The retina can repair some damage, but injury to the macular region can produce **blindness**.

Secondary bleeding in the eye can obscure vision beyond the area of the laser induced lesion.



Lasers may cause Photochemical Effects

- Laser light may be absorbed and converted to chemical energy. Chemical bonds within molecules of target tissue are broken directly by incident light or are excited into a biochemically reactive state.



Lasers may cause a Transient Acoustical Effect on Eye

When the retina is exposed to a pulsed laser, it is possible the heat cannot be dissipated by thermal conduction.

The superheated tissue can undergo an explosive change of state (pressure change). This shock wave can mechanically disrupt tissue and spread the area of damage.

Multiple pulses increase the damage. The force can produce a hole in the retina and choroid of the eye resulting in hemorrhage.

The retina can be detached. **Permanent vision loss is possible.** The injury can be extremely painful.



More on eye damage

Injuries to some parts of the eye can result in visual field defects. Injury to some parts of the eye can result in very severe pain. A long term effect of a laser injury to the eye is scarring. This alone can degrade vision for weeks to months after the initial injury.

**DAMAGE TO YOUR EYE FROM LASERS UP TO AND INCLUDING BLINDNESS CAN BE PERMANENT.
PROTECT YOUR VISION BY USING APPROPRIATE PROTECTIVE EYEWARE.
DIRECT VIEWING OF LASER BEAMS IS PROHIBITED.**



What do you need to know about Laser Eye Protection?

Use of appropriate eyewear may be the most effective safety measure for Class 3B and 4 lasers.

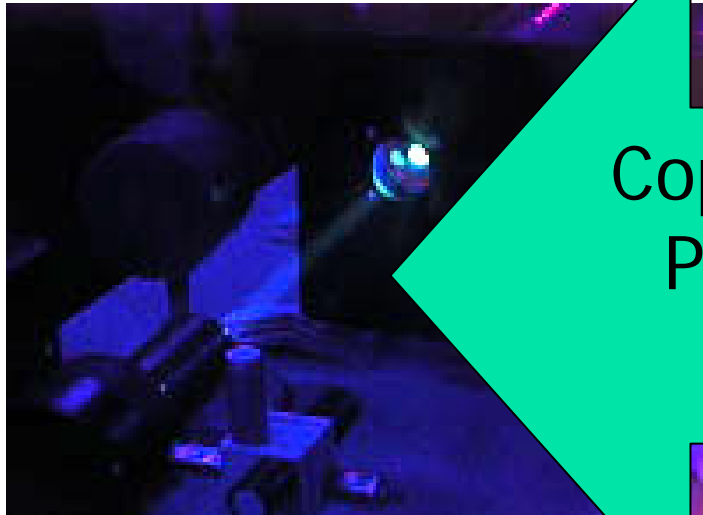
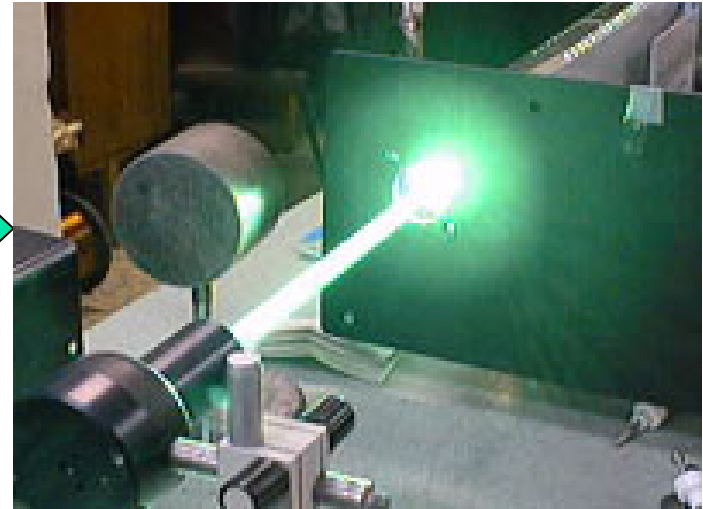
Be certain the eyewear is **appropriate for the wavelength and power of the laser in use**. It must block the correct wavelength and be of sufficient optical density [OD]. All eyewear must be labelled in terms of its OD and wavelength range.

Routinely inspect eyewear for any signs of damage. Replace worn or degraded elastic bands. Replace defective or damaged eyewear.

Everyone in the laser controlled area must wear the appropriate laser protection eyewear.

Laser Eye Protection

Copper Vapor Laser
without eye Protection



Copper Vapor Laser with eye
Protection – *note beam is
still slightly visible*



Laser Eye Protection links:

Optical Density Chart at Laser Vision:

<http://www.lasersafety.com/category.cfm?market=5&catid=1>

Overview page at Phillips:

<http://www.phillips-safety.com/Laser-Safety-Glasses/Index.htm>

Fisher:

General info on eye/face protection:

<https://www.fishersci.ca/uploadedFiles/Products/Safety/EyeFaceProtection.pdf>

eCATALOGUE: search for laser eyewear

<https://ecat.fishersci.ca/>

VWR: search for laser eyewear:

<http://www.vwrcanlab.com/index.cgi>

Laser radiation may also harm your skin!



- Thermal injury (BURN)
- Erythema (sun burn)
- Accelerated aging and pigmentation

Some people may be more at risk of photosensitive reactions from genetics or induced by medicines



How can you protect your skin from laser radiation?

Minimize skin contact with laser radiation by limiting the number of persons exposed:

- Only required personnel should be in the laser controlled area. Limit or prohibit spectators.
- Class 3B and 4 lasers should be used in sole use laboratories or enclosures and access controlled.
- Be certain scattered laser radiation is not escaping through windows to outside the laser controlled area.
- Cover up exposed skin. Consider wearing sunscreen.

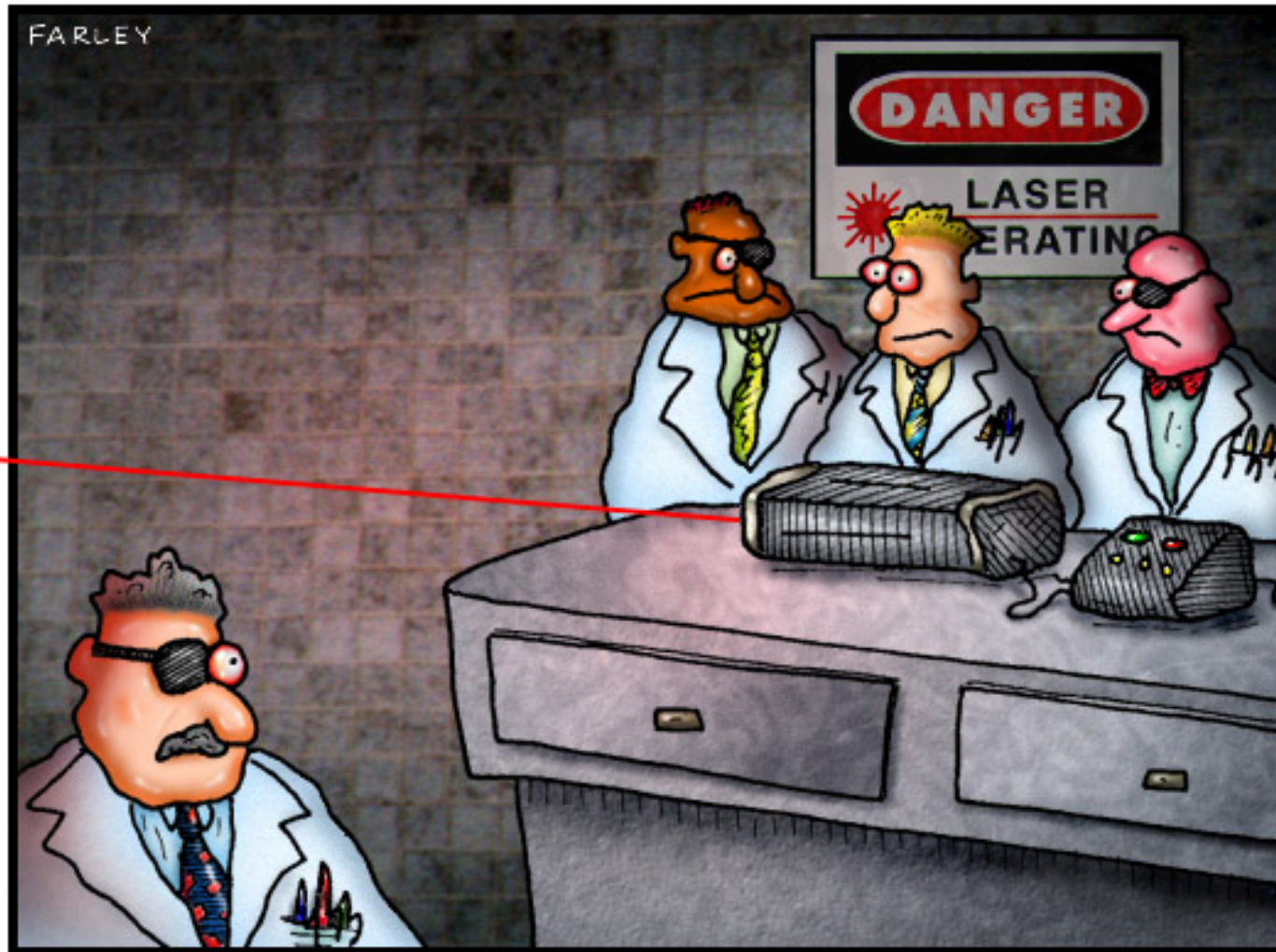


Protect yourself from Non Beam Hazards as well!

- Chemical – dyes – may be toxic or mutagenic. Organic solvents may be toxic, volatile or flammable.
- Electrical – several fatal accidents involving high voltage components associated with lasers have occurred in the U.S.
- Cryogenic coolant hazards – can cause burns. Can result in oxygen displacement.
- Fire hazards – most commonly associates with continuous wave lasers having output above half a watt. Appropriate fire fighting equipment should be present to control small fires only.
- Laser generated air contaminants, and other non laser related hazards such as the biosafety level of any samples or and any chemicals that may be in use.

DOCTOR FUN

26 June 97



Copyright © 1997 David Farley, d-farley@tezcat.com
<http://sunsite.unc.edu/Dave/drfun.html>

This cartoon is made available on the Internet for personal viewing only.
Opinions expressed herein are solely those of the author.

Peer pressure in the laser lab

Summary of Class 4 Laser Hazards

Direct laser radiation as well as diffuse and specular (mirror) reflections for a Class IV laser are hazardous and may result in ocular damage, specifically photochemical and thermal retinal injury, and/or skin damage including skin darkening and photosensitive reactions.



Summary of Class 4 Laser Hazards (cont)



- Potential electric shock hazard from the high voltage laser Power Supply Unit.
- Any Class IV laser product is a potential fire hazard.
- Potential fire/electric shock hazard as a result of a cooling water spillage/leak.
- If the correct key control is not implemented then there is the possibility that an untrained user could activate the laser. The potential consequences of this scenario include ocular/skin damage, fire and electric shock hazards etc.
- Cables and connectors lying across the laboratory present a possible trip hazard leading to potential bodily harm and/or equipment damage and system downtime.
- The use of a pulsed laser may present a risk to epileptics.

Who makes the rules for Laser Operation?





Governing Regulations

As of February 1, 2007 the province of Manitoba has implemented a revised Workplace Safety and Health Regulation.

Section 16.28 states: “An employer must ensure that a laser used in the workplace is installed, used and maintained in accordance with ANSI Standard Z136.1-2005, American National Standard for the Safe Use of Lasers”.



Who is Responsible for the Safe Use of Lasers?

- Departments that have lasers
- Environmental Health and Safety Office
- Individual operating a laser



Departments are responsible:

- Departments have ultimate control over laser operation and are responsible to ensure that lasers are used in accordance with the new regulatory requirements and referenced standards.



Departments must ensure:

Control measures are implemented by the Departmental Owner of each Laser to reduce the possibility of human exposure to hazardous laser radiation and the associated hazards (non-beam hazards).

HOWEVER: When a laser or laser product is located within a workspace that is not under the sole control of the Departmental Owner of the laser, the Department Head controlling access to the space must recognize and implement controls to protect all the occupants of the work area in conjunction with the Departmental Owner.



To comply with the Regulations:

Ideally, a qualified Laser Safety Officer would review all laser facilities and procedures.

The Laser Safety Committee is working to identify a qualified Laser Safety Officer.

In the interim, as a precaution, the Departmental Owner of Laser is responsible to ensure that the laser hazards are controlled.



Laser Safety Officer (LSO)

The Laser Safety Officer (LSO) shall be an individual whose training and experience is sufficient to be able to provide knowledgeable evaluation and control of laser hazards. The duties of the LSO shall include:

- Review of the University of Manitoba Laser Safety Program and make recommendations for improvements.
- Classify or verify the classification of lasers and laser systems.
- Provide hazard evaluation in accordance with ANSI Z136 standards.
- Assess implementation and effectiveness of prescribed control measures.
- The LSO may make recommendations of substitute controls when the primary controls are not valid or to avoid unnecessary duplication.



To comply with the Regulations:

For each Class 3B and 4 Lasers, an assessment of the Maximal Permitted Exposure (MPE), Nominal Hazard Zone (NHZ) and for lasers operating in the ultraviolet, MPE-skin should be undertaken.

This information can be used to determine the Laser Controlled Area (LCA) and to be safe, the LCA must equal or exceed the NHZ .

Unless approved by a qualified Laser Safety Officer, the NHZ/LCA is defined as the whole room or enclosure that may be exposed to laser radiation during operation.

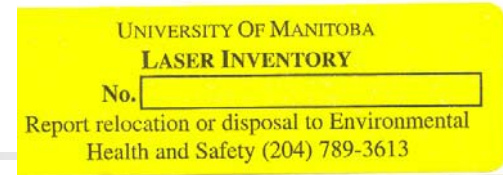
Control measures shall be implemented to reduce the exposure of humans to below the applicable MPE.



The Environmental Health and Safety Office is responsible:

- To provide assistance and guidance so Departments can meet their responsibilities to provide a safe working environment for staff and students using lasers.

At the UofM, there is Registration of Lasers



- The Environmental Health and Safety Office, in conjunction with The University of Manitoba Laser Safety Committee, has initiated a registration program for all Class 3B and 4 lasers.
- This registration is the first step to assess the compliance with the new regulation and develop a comprehensive program.



Individuals are responsible:

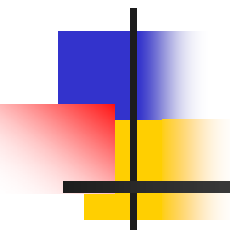
- Ensure the laser is registered with EHSO
 - look for the UofManitoba Laser Inventory sticker
- Individuals are responsible to take all reasonable precautions to ensure their own safety, and the safety of other persons. All laser use is to be performed in a manner that will minimize radiation exposure.
- Individuals must not initiate or participate in any activity that may endanger the health or safety of anyone.



Every individual has 4 rights/ responsibilities for workplace safety:

- **Right to Know** about workplace hazards, including how to identify hazards and protect themselves from those hazards, and about the rights afforded to workers under the Act.
- **Right to Participate** in decisions related to workplace safety and health, free of reprisal for their participation. Participation, in part, is achieved through consultation with the committee or representative.
- **Right to Refuse** dangerous work.
- **Right to Protection from Discrimination** protects these rights by prohibiting employers from imposing discipline or other sanction on workers for fulfilling their responsibilities or exercising their rights.

Control Measures for Class 3B and 4 Lasers





Laser Control Measures (Class 3B and 4)

- Control of access to Laser Controlled Area
- Laser Warning Sign at entrance
- Training and the establishment of departmental operating procedures (including PPE) should be completed.
 - Impacts related to ancillary staff (physical plant, security, EHSO) and visitors should be included.
- An assessment on non beam hazards is also required



Laser Controlled Area

Prior to operation, it is incumbent upon the Departmental Owner of each laser to ensure the laser is located in a facility, room or enclosure with the following minimum physical and administrative features:

A **Laser Controlled Area** shall be defined to contain the laser radiation. The room or enclosure must shield the public areas to ensure that members of the public may not be inadvertently exposed to laser radiation or non-beam hazards associated with the use of the laser.

Access to Laser Controlled Area

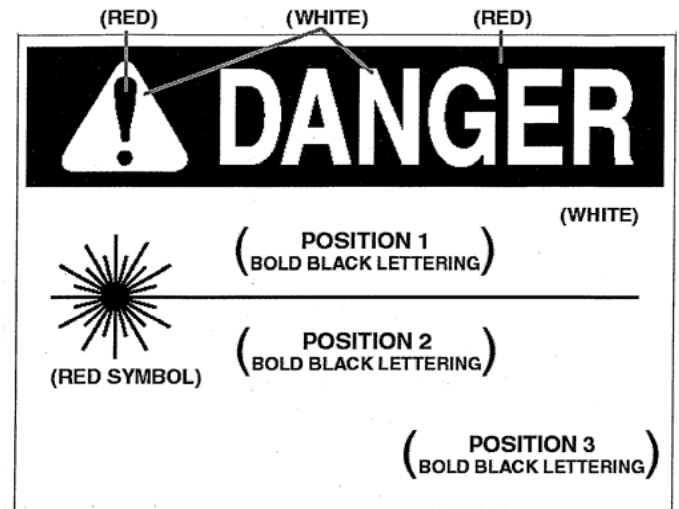


- The **access to the laser key** shall be restricted to the departmental owner and authorized Laser Operators. The Laser Operator shall be trained to operate the specific laser safely and shall be responsible to ensure the site specific Laser SOPs are followed while supervising everyone within the Laser Controlled Area.
- During all operation, maintenance and servicing, **access to the Laser Controlled Area** shall be limited to a Laser Operator as authorized by the Departmental Owner or persons supervised by the authorized Laser Operator.

Laser Warning Sign

The Laser Controlled Area shall be posted with the appropriate warning sign in accordance with ANSI Z136.1

AMERICAN NATIONAL STANDARD Z136.1 - 2000 Fig. 1b
Sample Warning Sign for Certain Class 3a Lasers and for Class 3b and Class 4 Lasers





Laser Warning Sign

Position 1 states, as appropriate:

- Laser Protective Eyewear Required, or
- Invisible Laser Radiation
- Knock Before Entering
- Do Not Enter When Light Is On
- Restricted Area

Position 2 states the type of laser (Nd:Yag etc)

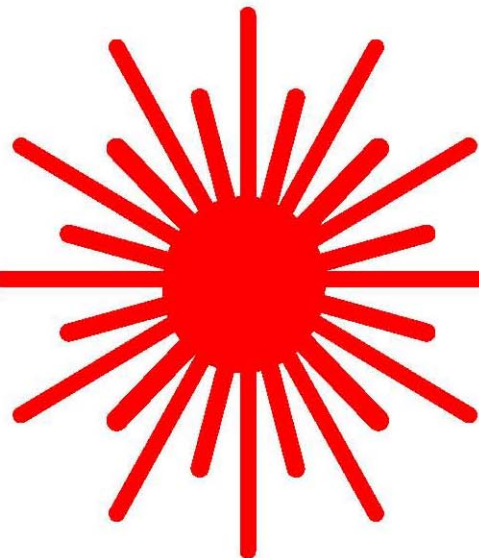
Position 3 states the class of laser in operation

Non-beam hazards shall be clearly communicated at the entrance as well.



DANGER

**Invisible and/or Visible Laser Radiation
Avoid Direct Eye Exposure**



Laser Type(s): Output(s) Wavelengths:

Class 4 Laser

Departmental Owner of Laser (phone and office location): _____

Departmental Laser Safety Contact (phone and office location): _____

For further information contact the University of Manitoba:

Radiation Safety: 789-3613 Environmental Health and Safety Office: 7474-6633

24-hour Emergency: Contact Security Services at 555 or 474-9341



Laser Safe Operating Procedures (SOPs)

- Laser Control Measures are documented in **Laser SOPS** that are site specific and appropriate for each type of experiment or procedure involving the laser.
- Control of non beam hazards should be included. The safety of ancillary staff is to be considered in defining Laser SOPS.
- When possible engineering controls shall be implemented before administrative procedures or personal protection.



SOPs implemented for the various functions performed with the Laser:

- OPERATION MODE: Laser classification is based on the designed output in the operation mode and Laser SOPs must be developed to mitigate the risks associated with the laser classification.
- MAINTENANCE MODE: Maintenance would be limited to tasks associated with assuring the routine performance of the laser such as cleaning and replacing expendables and additional precautions may be required to ensure safety.
- SERVICE MODE: Service would include the non-routine replacing or repairing faulty parts and may include access to the beam requiring additional control measures.



Samples of SOPs

Cambridge University Local Rules (PIV):

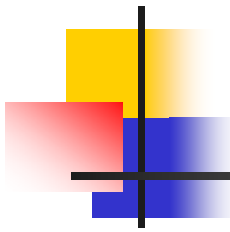
http://www-g.eng.cam.ac.uk/photonics/laser/LR_PIV_fluids_02_05.pdf

Purdue University Laser SOP (includes PIV):

<http://www.ecn.purdue.edu/microfluidics/lab/SOP-lastersafety.pdf>

Class 3B or 4 Argon Laser SOP:

http://www.umanitoba.ca/admin/human_resources/ehso/images/SOP_for_Class_3B_or_Class_4_argon_laser.pdf



Minimum Laser Control measures for class 3B lasers shall include:

- Activation warning system: chime, light or verbal count down, and
 - Warning light must be visible through protective eyewear, and
 - Viewable within the occupied regions of the Laser Controlled Area
- Operation of the Laser shall ensure the beam is well defined and limited within the controlled space.
- Consideration shall be given as appropriate to:
 - Terminate any potentially hazardous beam in a beamstop of an appropriate material.
 - Locate the exposed beam above or below eye level of everyone in the room
 - Provide all persons within the Laser Controlled Area with appropriate eye protection
 - Cover all windows, doorways, open portals to reduce the transmitted radiation.

Minimum Laser Control Measures for Class 4 lasers shall include:



- Room or occupied enclosure shall facilitate rapid egress in an emergency
- A clearly marked "Panic Button" to deactivate the laser below MPE (should be red and mushroom shaped).
- Entryway to Laser Controlled Area must have one of the following:
 - Non-defeatable Area/Entry Control Interlocked with Laser, or
 - Defeatable Entry controls may be appropriate if there is no hazardous radiation at the entry way
 - Procedural Entry Control if
 - Everyone with access has adequate training and PPE is provided at entry
 - A door, blocking barrier or screen attenuates the laser radiation at the entry point
 - There is a visible or audible signal indicating the laser is activated.



University Rules for Class 3B and 4 Lasers

1. Authorized, trained users only. Class 3B and 4 lasers require that laser key is secured from unauthorized users.
2. Restrict access to room when laser is in operation
3. Register Class 3B and 4 lasers with EHSO
4. Enclose the beam path. Interlock entrances.
5. Keep the beam path below eye level whether seated or standing.
6. Eliminate specular surfaces.
7. Terminate primary and secondary beams at the end of their useful path.
8. Use low power settings to reduce the beam power.
9. Limit spectators and be sure they are aware of the hazards.
10. Unattended operation is prohibited.
11. Use appropriate PPE and signage.



University Rules for all Lasers

1. Individuals are responsible to take all reasonable precautions to ensure their own safety, and the safety of other persons.
2. All laser use is to be performed in a manner that will minimize radiation exposure.
3. Do not aim the laser at doors, windows or specular surfaces. Specular surfaces reflect laser radiation.
4. Direct viewing is prohibited.
5. Turn the laser off when it is not in use.
6. Individuals must not initiate or participate in any activity that may endanger the health or safety of anyone.



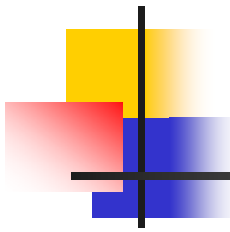
Causes of laser accidents

- 95% of accidents are due to unanticipated eye exposure during alignment, misaligned optics and upwardly directed beams when available eyewear was not being used.
- Other causes include equipment malfunction, intentional exposure, operator being unfamiliar with the equipment, and failure to follow standard operating procedures.
- Fatigue is a common cause of accidents. Do not operate laser equipment when tired or impaired.



Reporting Accidents

- ANYONE WITH A KNOWN OR SUSPECTED EYE INJURY SHOULD OBTAIN **IMMEDIATE** MEDICAL ATTENTION. TIME OF TREATMENT CAN OFTEN CHANGE THE OUTCOME AND REDUCE LONG TERM EFFECTS.
- Call EHSO as soon as feasible at 474-6633 or 555 after hours.



Before you use a class 3B or 4 laser at the University of Manitoba, make sure you know:

- ✓ What are lasers hazards
- ✓ How to identify lasers in your work area
- ✓ How to work safely with lasers
- ✓ How to work safely around others



Review of Laser Control Measures

(Class 3B and 4)

- Laser Warning Sign at entrance
- Control of access to Laser Controlled Area
- Training and the establishment of departmental operating procedures (including PPE) should be completed.
 - Impacts related to ancillary staff (physical plant, security, EHSO) and visitors should be included.

An assessment of non beam hazards is also required

Acknowledgement

This completes the Laser Safety Information package.

(Please read and complete the following, print a copy and forward it to your supervisor)

I acknowledge having completed the Laser Safety Information package and I have read and understood the information presented. In particular, I understand my rights and responsibilities as an individual working with or around lasers at the University of Manitoba.

If I have questions on any matter, I also acknowledge that I may contact my supervisor or the Environmental Health & Safety Office for clarification.

EMPLOYEE SIGNATURE

DATE

EMPLOYEE NAME (Please PRINT)

SUPERVISOR SIGNATURE

DATE

SUPERVISOR NAME (Please PRINT)

