

Laser Radiation Safety

02/21/2003

Laser Safety

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Laser Safety

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Laser Acronyms Listing

AEL - Accessible Emission Limit

ANSI - American National Standards Institute

CW - Continuous Wave

EL - Exposure Limit

IR - Infrared

J - joule

LASER - Light Amplification by the Stimulated Emission of Radiation

OD - Optical Density

PRF - Pulse Repetition Frequency

RDTE - Research, Development, Testing and Evaluation

SOP - Standing Operating Procedure

UV - Ultraviolet

USACHPPM - U.S. Army Center for Health Promotion and Preventive Medicine

Laser Safety

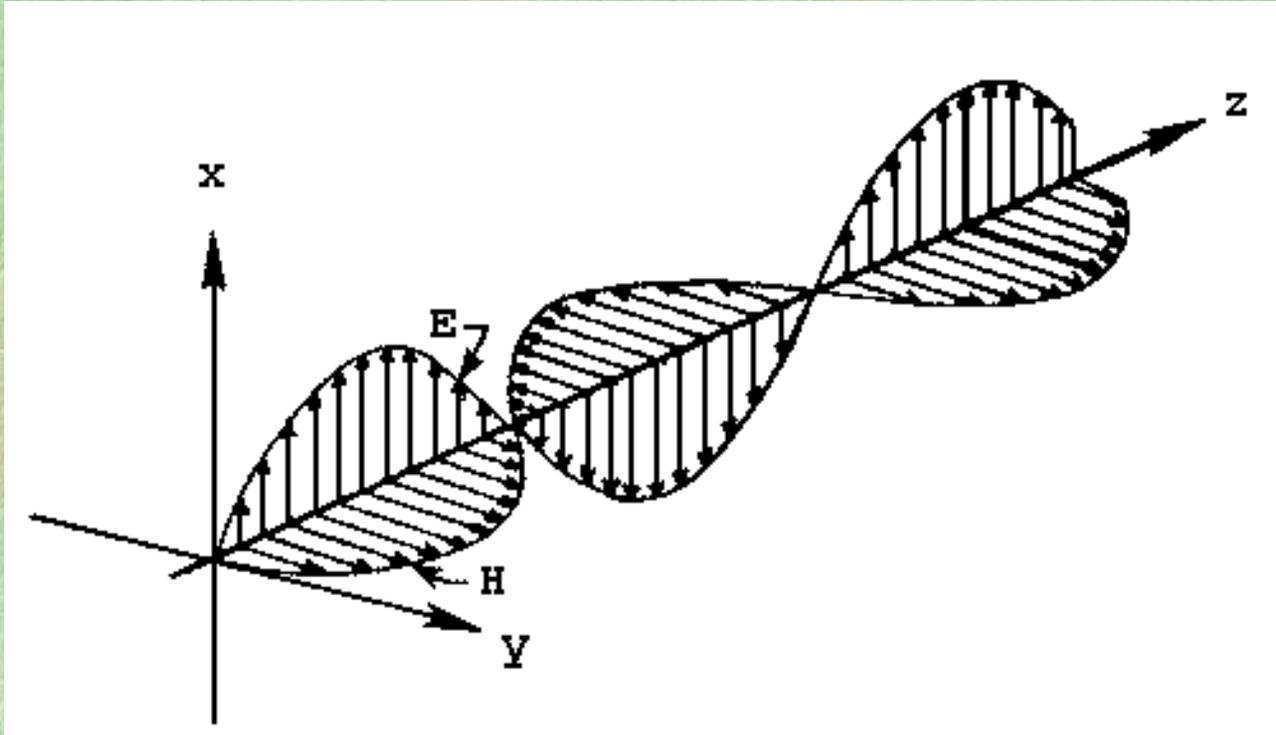
Introduction

Electromagnetic Radiation:

The transverse propagation of energy consisting of alternating electric and magnetic fields which travel through space at the velocity of light

Laser Safety

Introduction (cont'd)

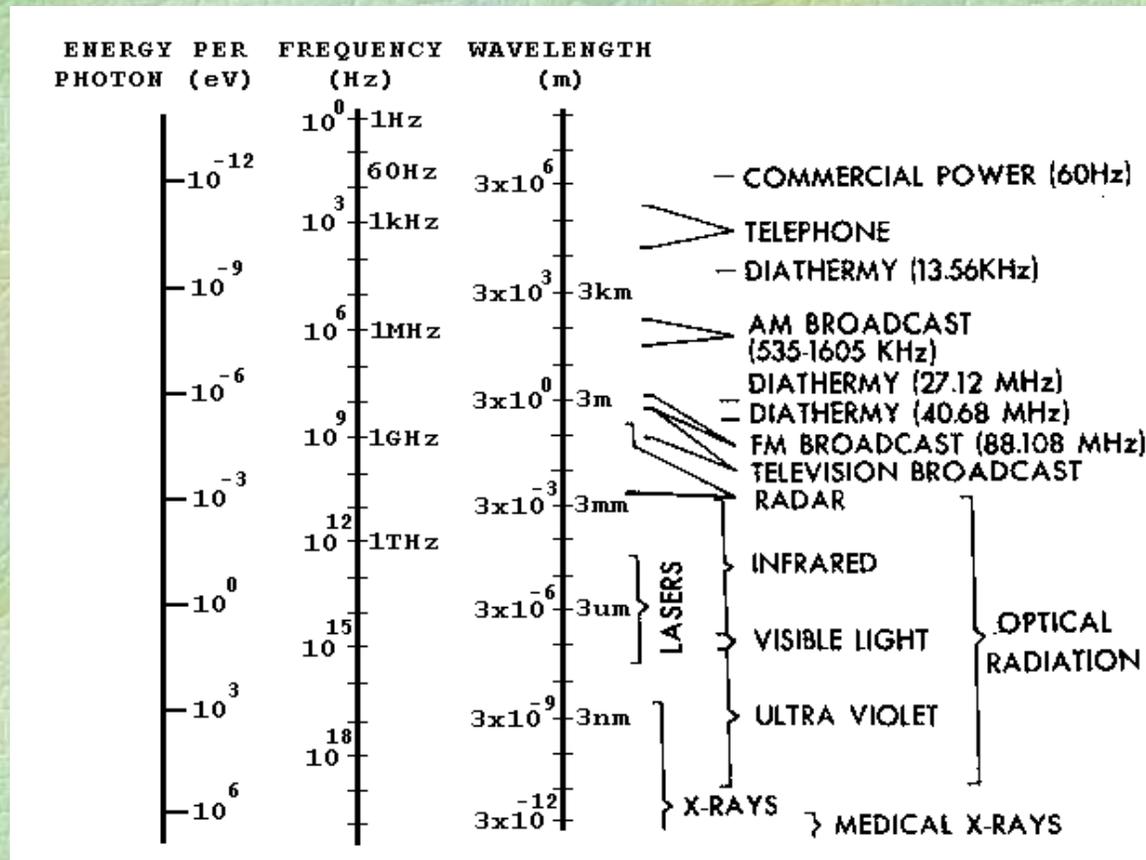


$$f \lambda = c$$

$$E = hf$$

Laser Safety

Introduction (cont'd)



Laser Safety

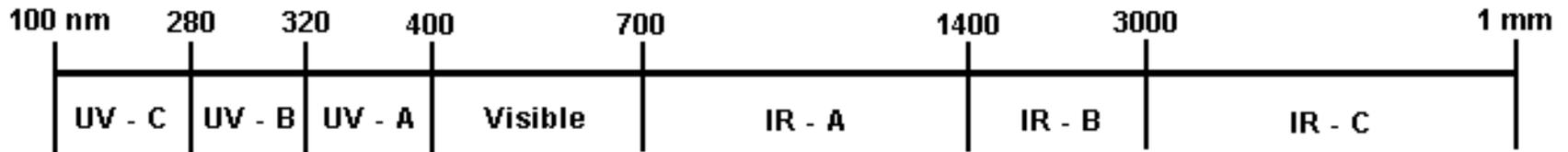
Introduction (cont'd)

Optical Radiation:

Electromagnetic radiation with wavelengths which lie within the range of 200nm to 1000um (1mm)

Laser Safety

Introduction (cont'd)



UV-A

Argon

N₂

Excimer

Visible

HeNe

Ruby

Argon

Dye

Krypton

Doubled Nd:YAG

IR-A

Semiconductor

Nd:YAG

Nd:Glass

IR-B/C

CO

CO₂

Laser Safety

Introduction (cont'd)

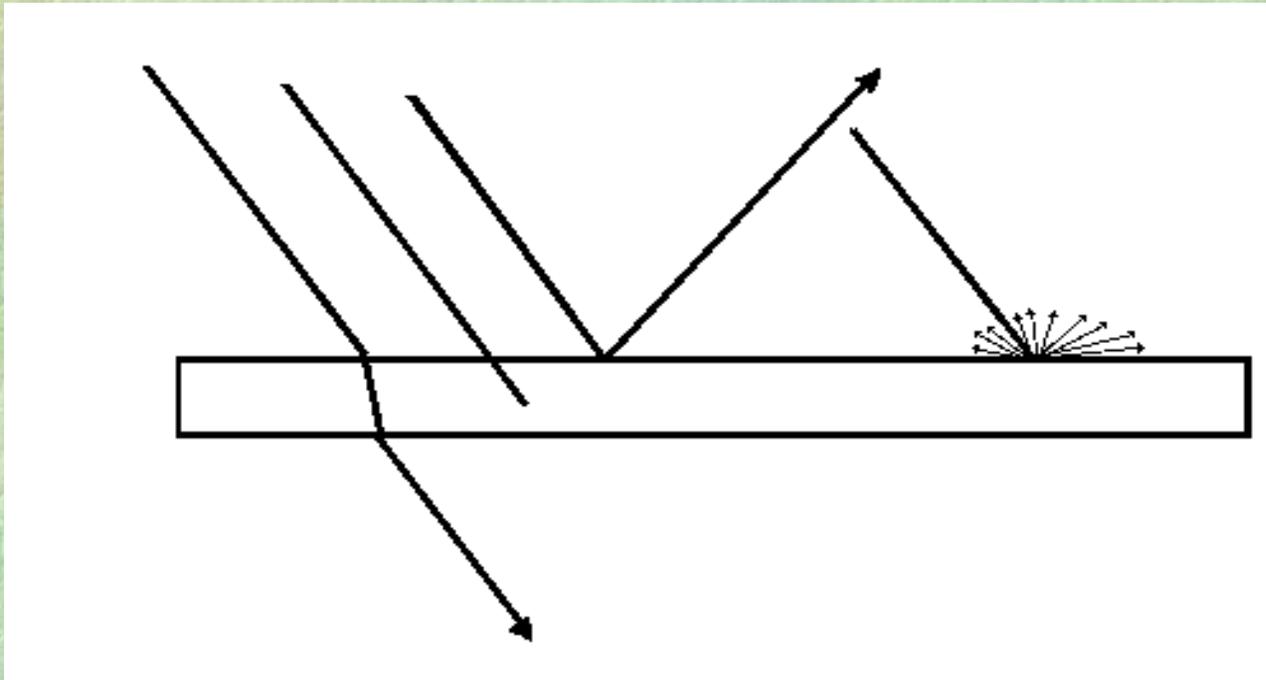
LASER (Light Amplification by the Stimulated Emission of Radiation):

Any device which can produce or amplify optical radiation primarily by the process of stimulated emission and operating with a wavelength of 200nm to 1mm

Laser Safety

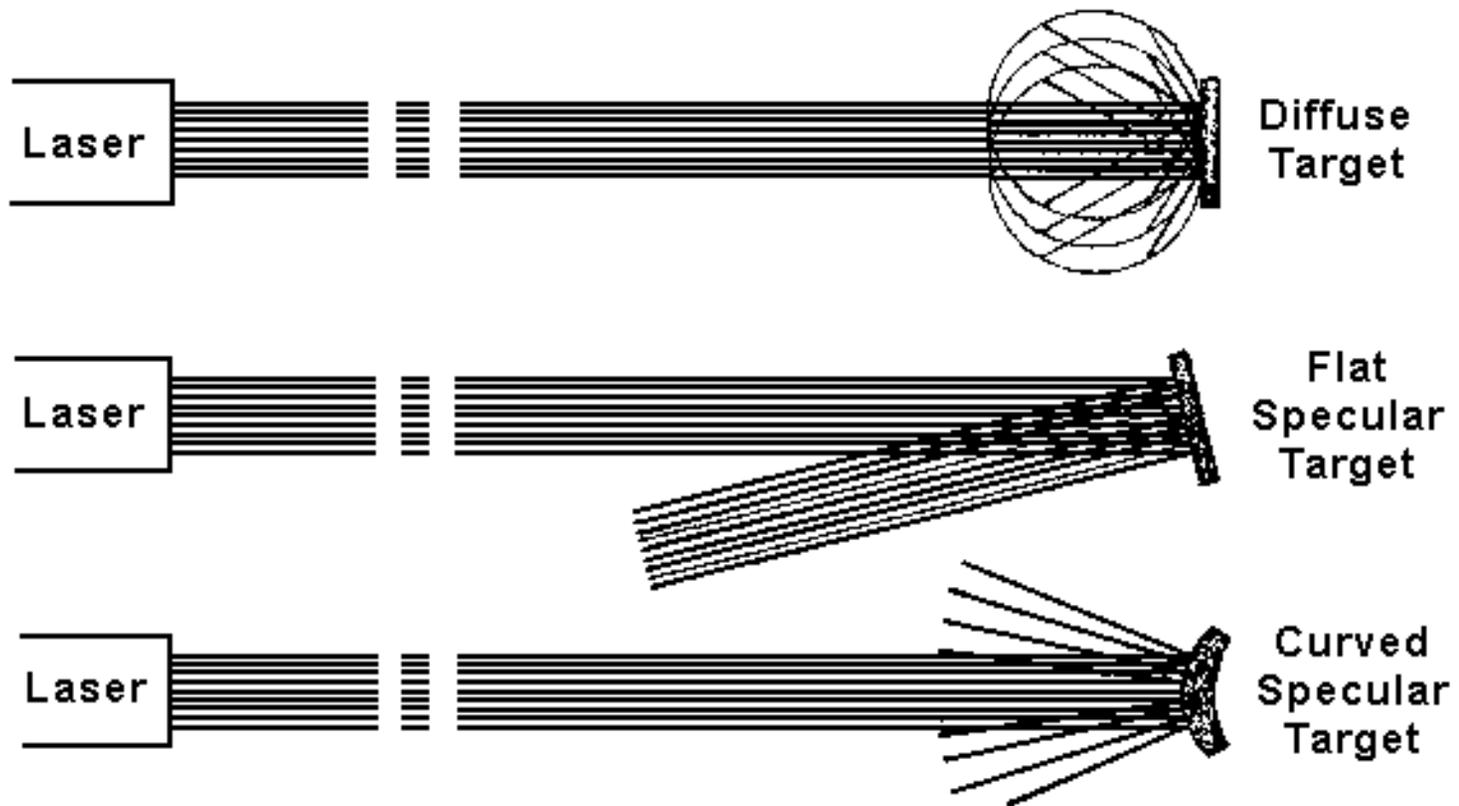
Introduction (cont'd)

- Light can be transmitted, absorbed or reflected



Laser Safety

Introduction (cont'd)



Laser Safety

Introduction (cont'd)

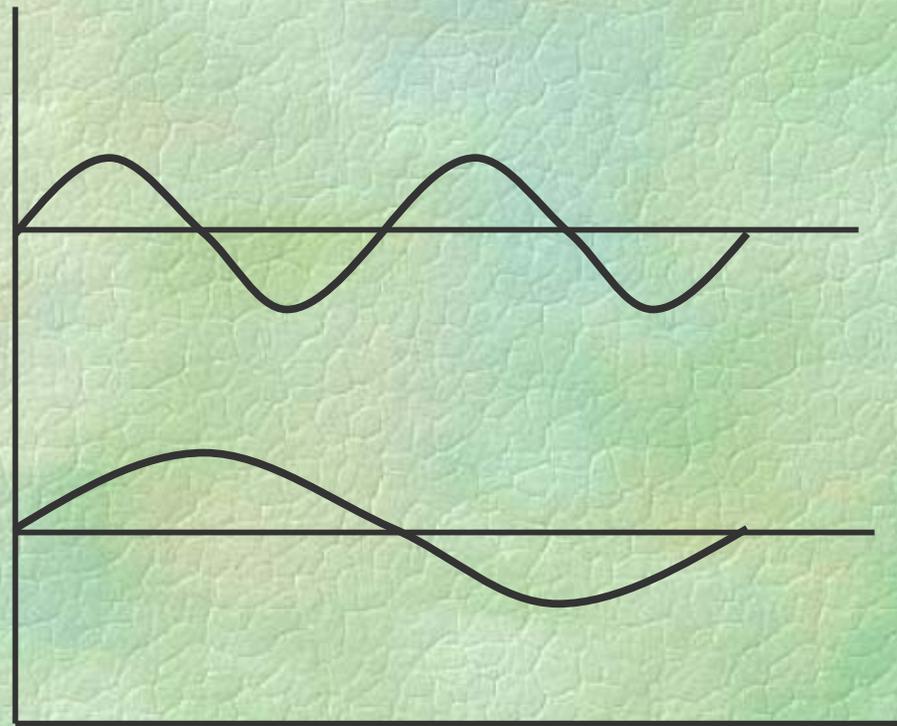
☞ Monochromatic

☞ Directional

☞ Coherent

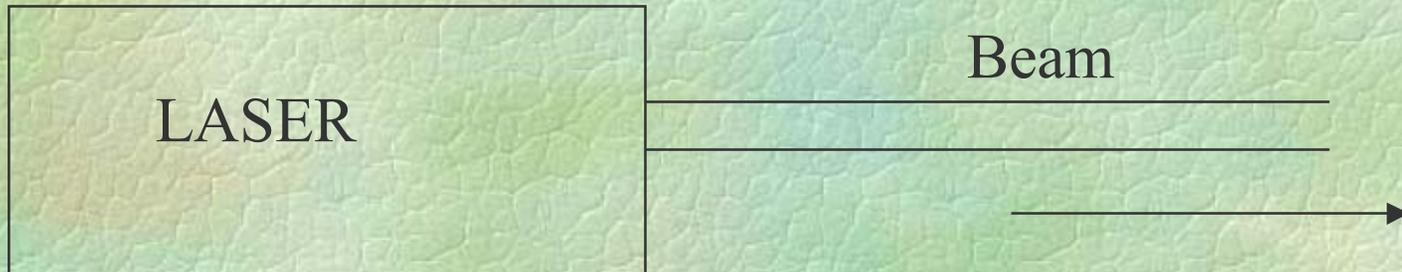
Laser Safety

Introduction (cont'd)



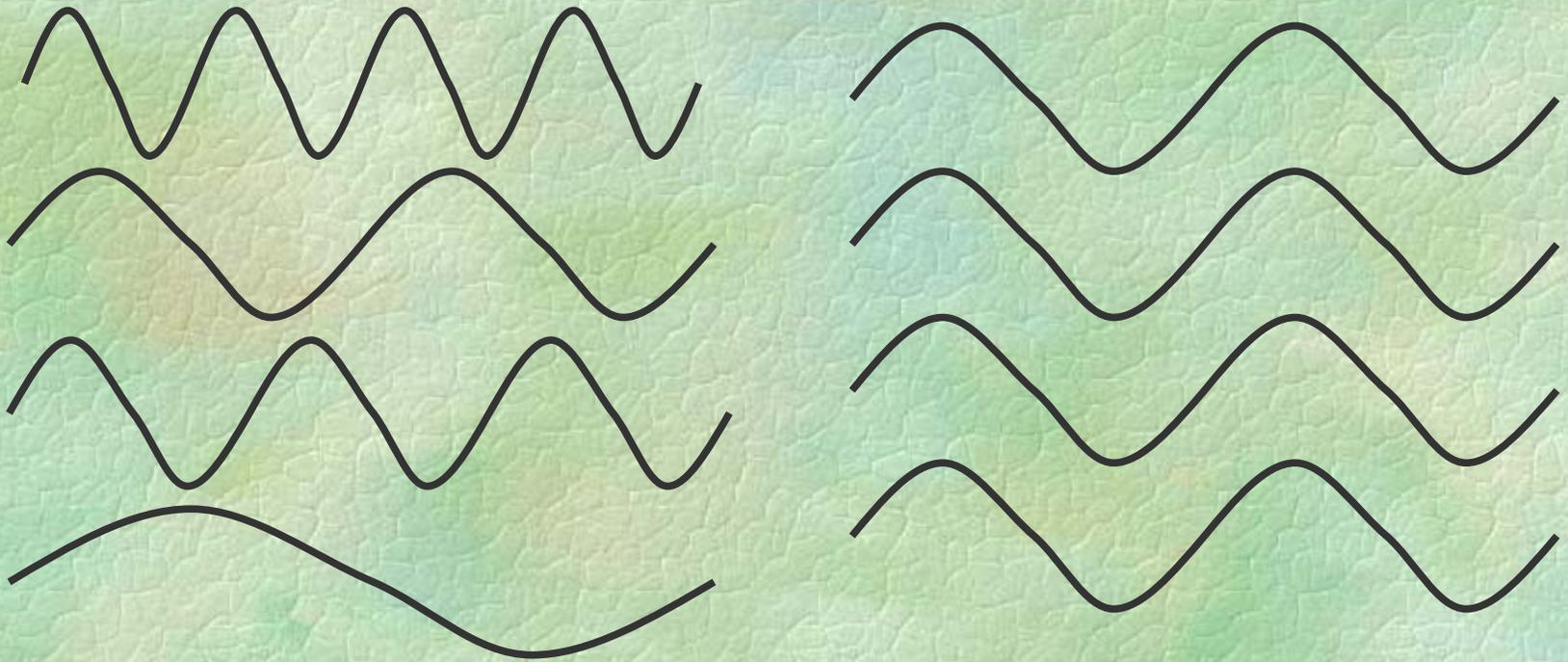
Laser Safety

Introduction (cont'd)



Laser Safety

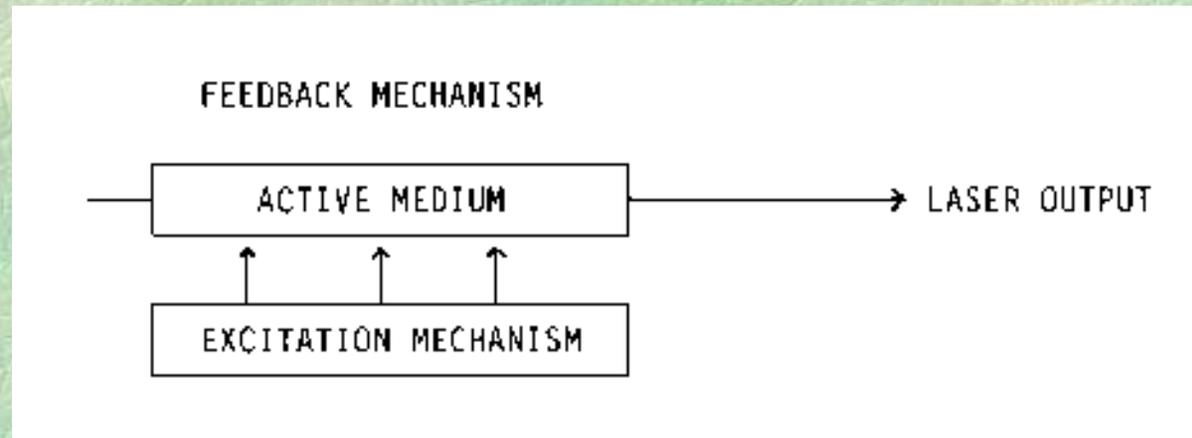
Introduction (cont'd)



Laser Operation

❖ Four Basic Elements

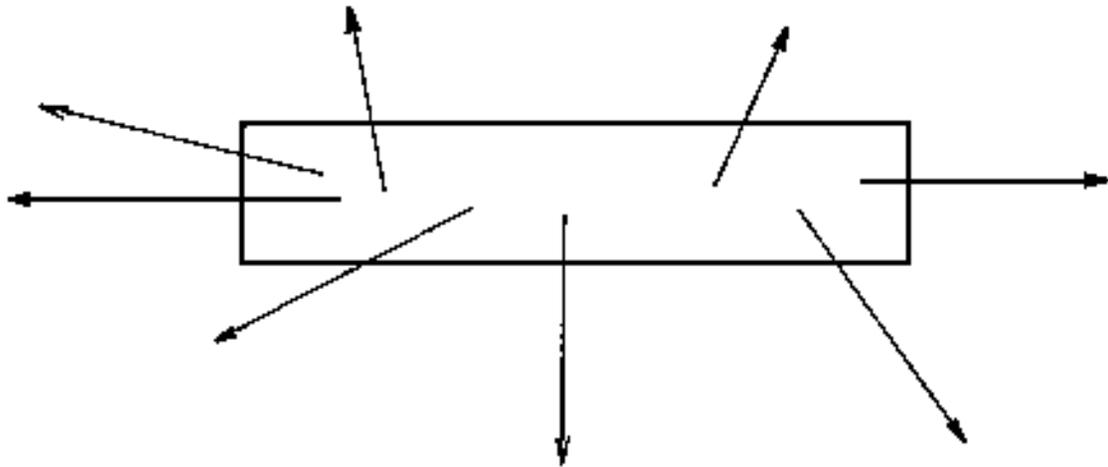
- Active Medium
- Excitation Mechanism
- Feedback Mechanism
- Output Coupler



Laser Operation

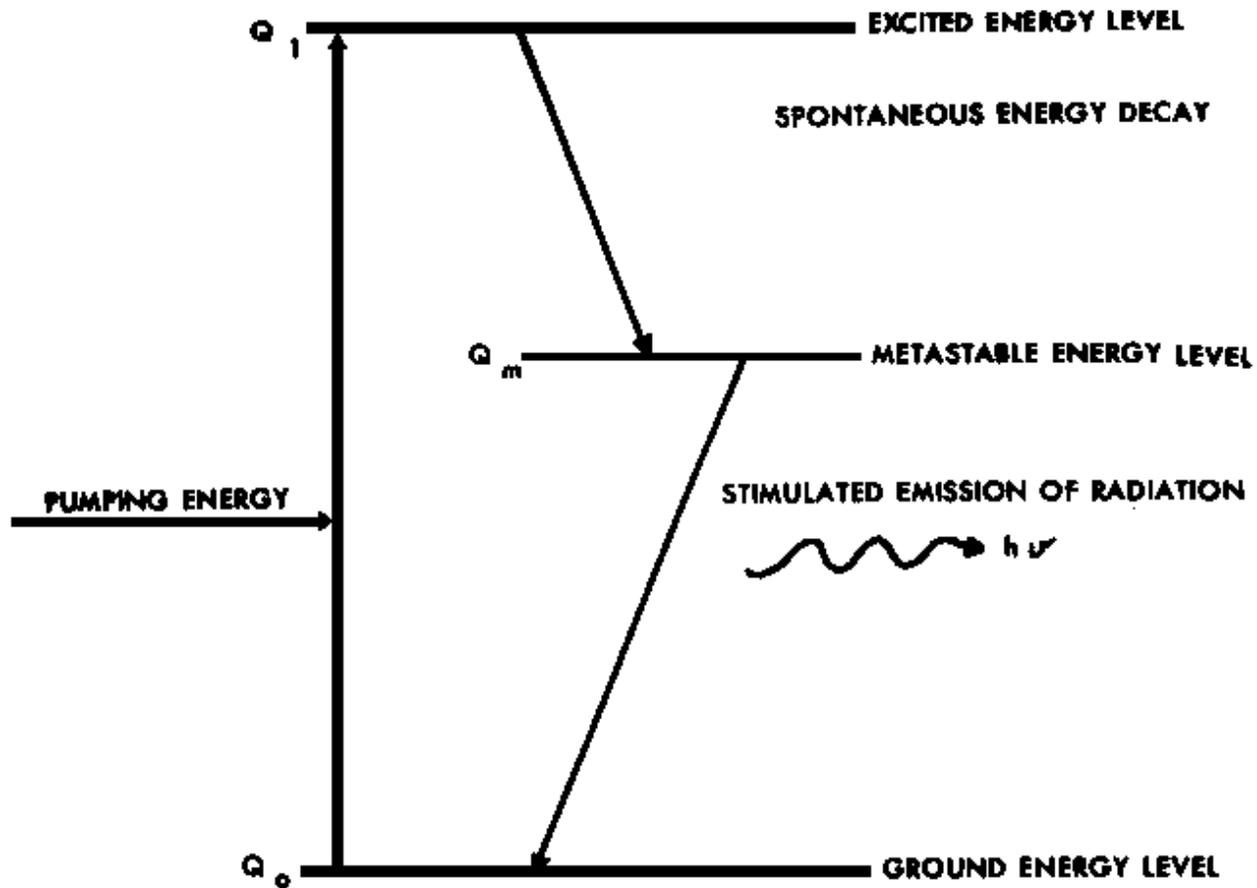
Active Medium

- ❖ Can be a gas, solid or glass crystal, a dye, or a semiconductor material
- ❖ Light is emitted through a process called stimulated emission



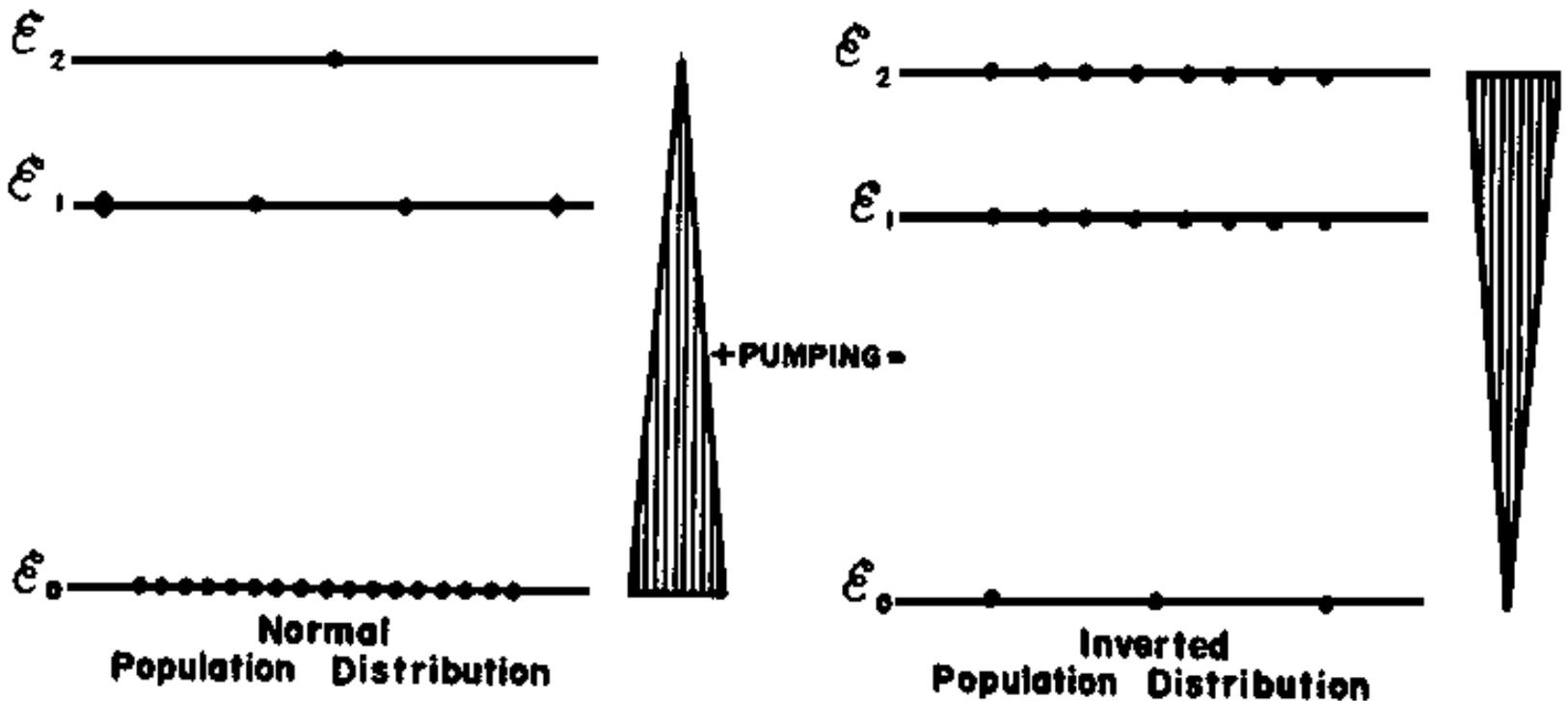
Laser Operation

Active Medium (cont'd)



Laser Operation

Active Medium (cont'd)



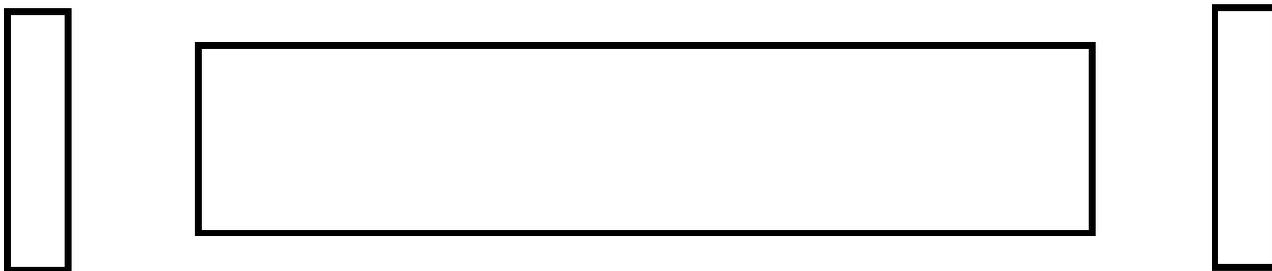
Laser Operation

Excitation Mechanism

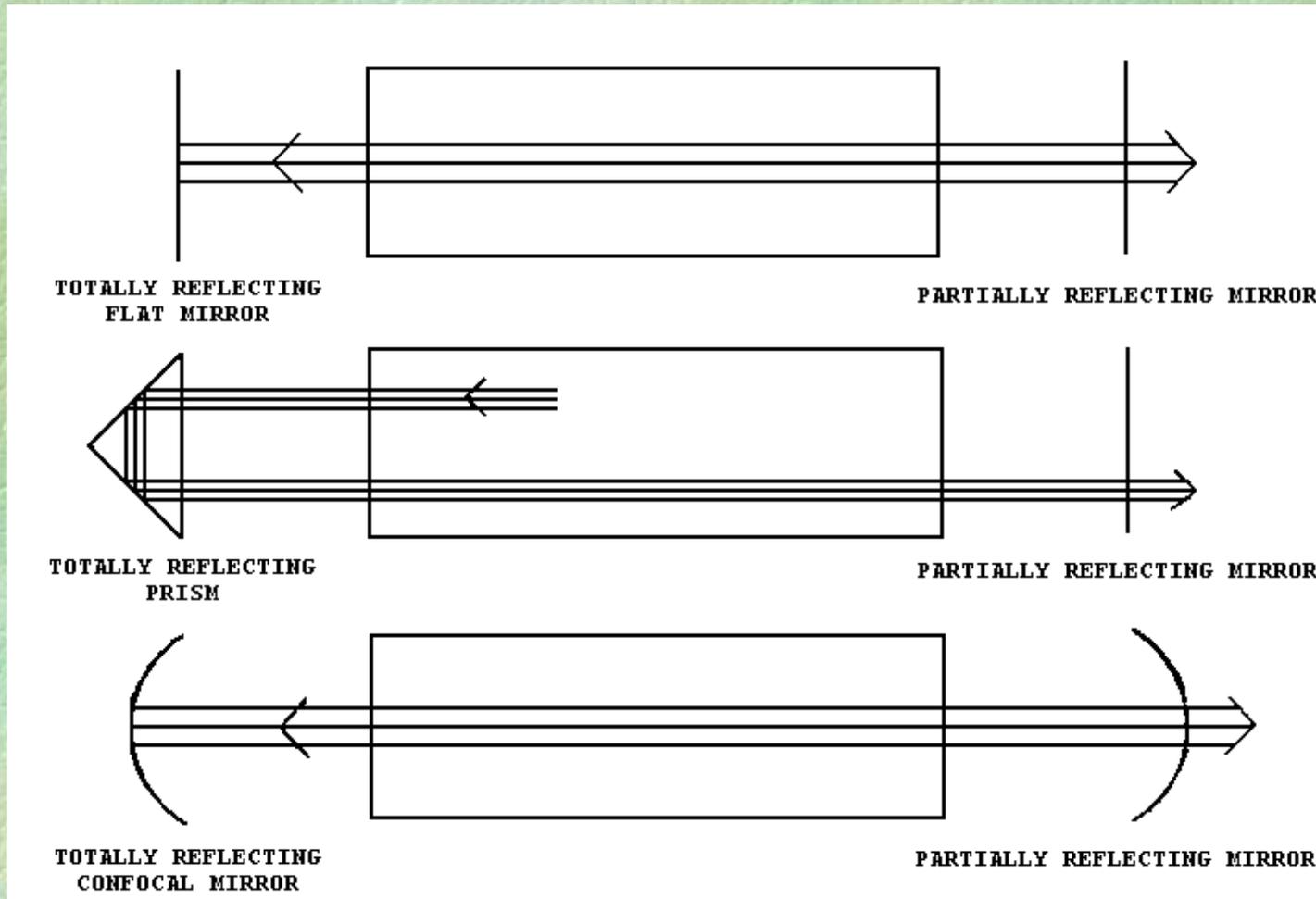
- ✿ The source of energy for the active medium
- ✿ Can be in the form of:
 - Electrical energy
 - Flashtube or lamp
 - Another laser

Laser Operation Feedback Mechanism

- ✿ Typically, two mirrors placed at each end of the active medium
- ✿ One mirror is partially transparent. This is known as the output coupler



Laser Operation



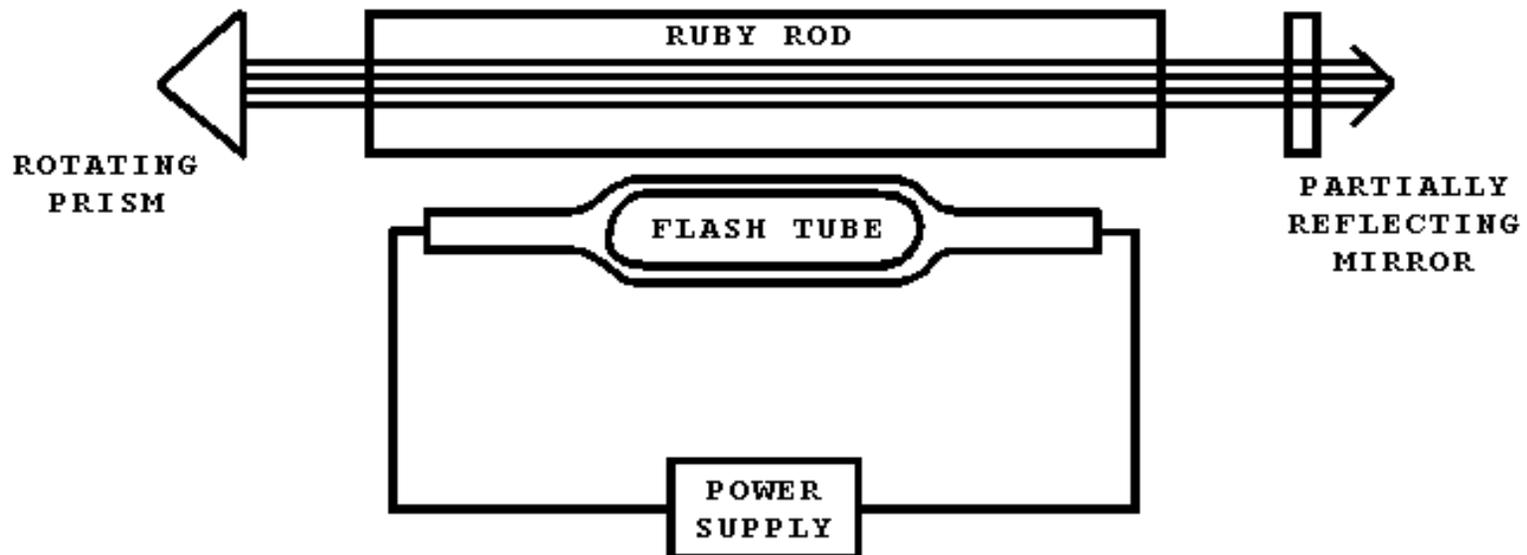
Laser Types

- ✿ Crystal or Glass Rods (Ruby, Nd:YAG)
- ✿ Gas (HeNe, Argon, CO₂)
- ✿ Liquid (Dye)
- ✿ Semiconductor Material (Diodes)

Laser Types

Crystal or Glass Rods

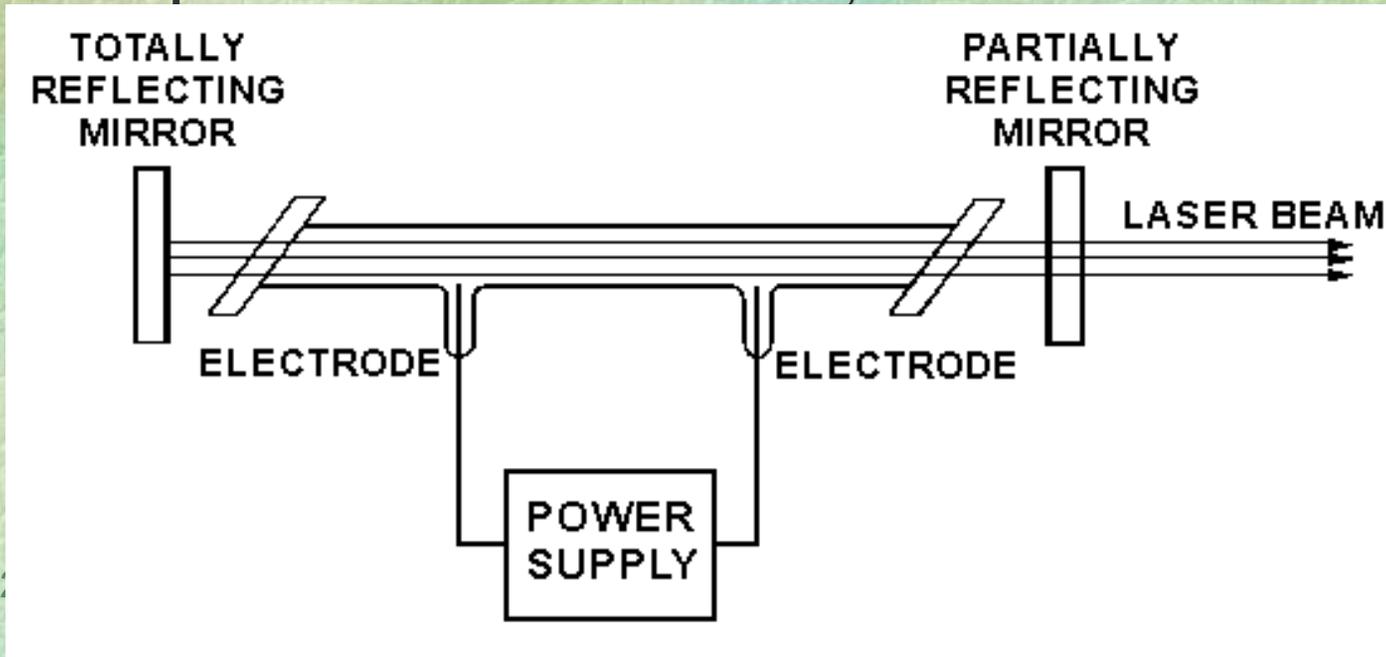
- ❖ Active Medium: Solid crystal or glass
- ❖ Excitation Mechanism: Flashtube or lamp
- ❖ Examples: Ruby, Neodymium-YAG, etc.



Laser Types

Gas Lasers

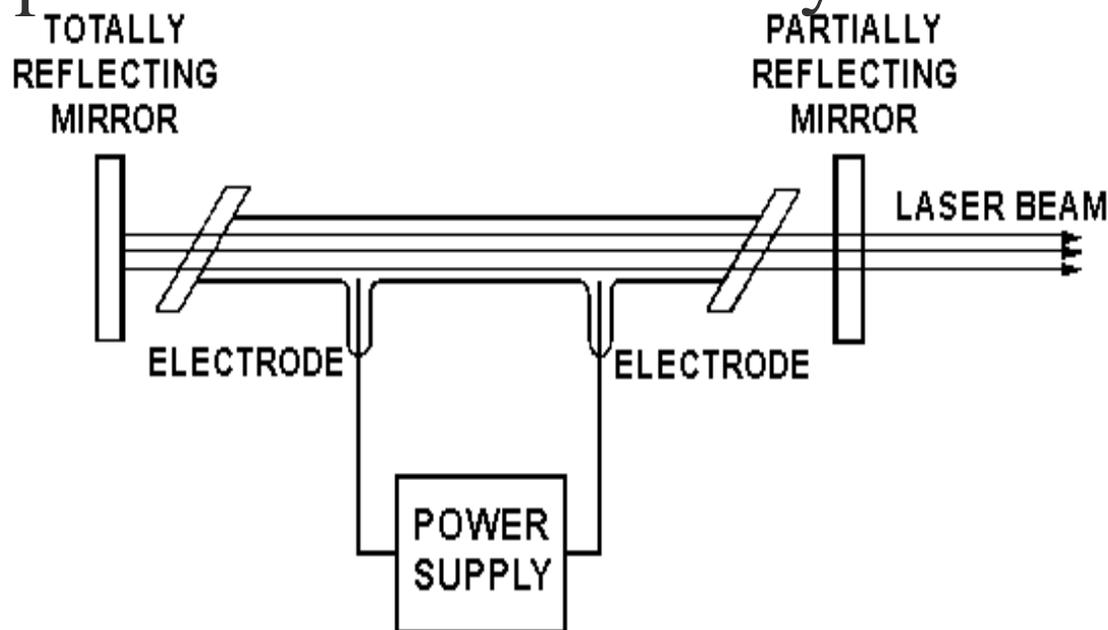
- ❖ Active Medium: Gas enclosed in glass tube
- ❖ Excitation Mechanism: Electrical Energy
- ❖ Examples: Helium-Neon, Carbon Dioxide



Laser Types

Dye Lasers

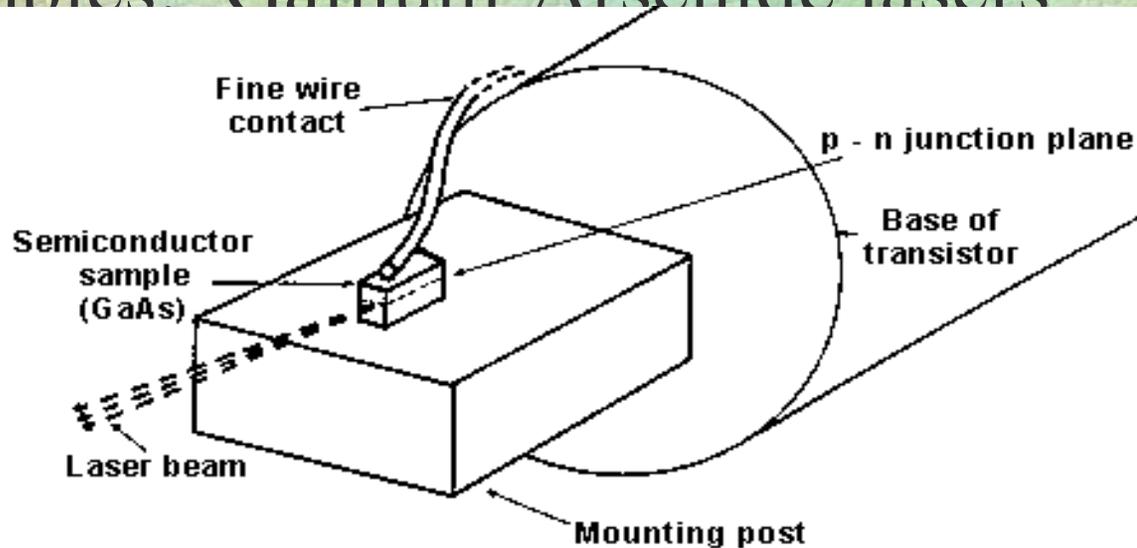
- ❖ Active Medium: Organic dye in alcohol
- ❖ Excitation Mechanism: Flashlamp or laser
- ❖ Examples: Rhodamine 6G dye laser



Laser Types

Semiconductor Lasers

- ❖ Active Medium: The p-n junction between two semiconductor materials
- ❖ Excitation Mechanism: Electrical Energy
- ❖ Examples: Gallium-Arsenide lasers



Laser Safety

Modes of Operation

- Continuous Wave

- Normal Pulse

- Q-switched Pulse

- Mode-locked Pulse

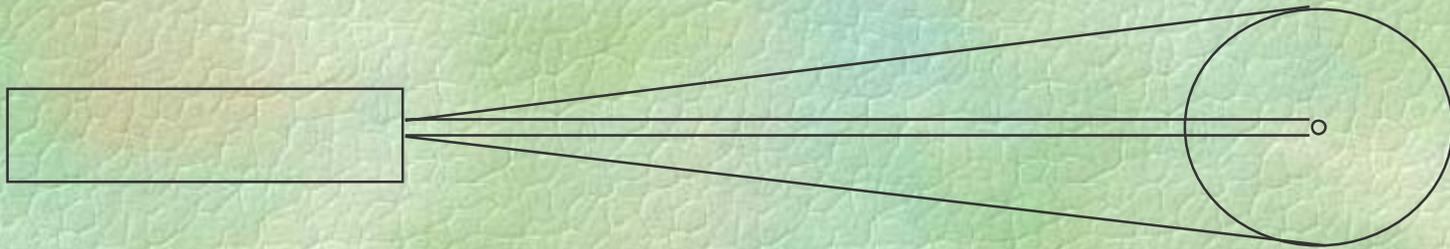
Laser Safety

Modes of Operation (cont'd)

- ❧ Wavelength, beam diameter, beam divergence
- ❧ Continuous Wave Lasers
 - Average Power
- ❧ Pulsed Lasers
 - Peak power, pulse repetition frequency, pulse duration, energy/pulse, duty cycle

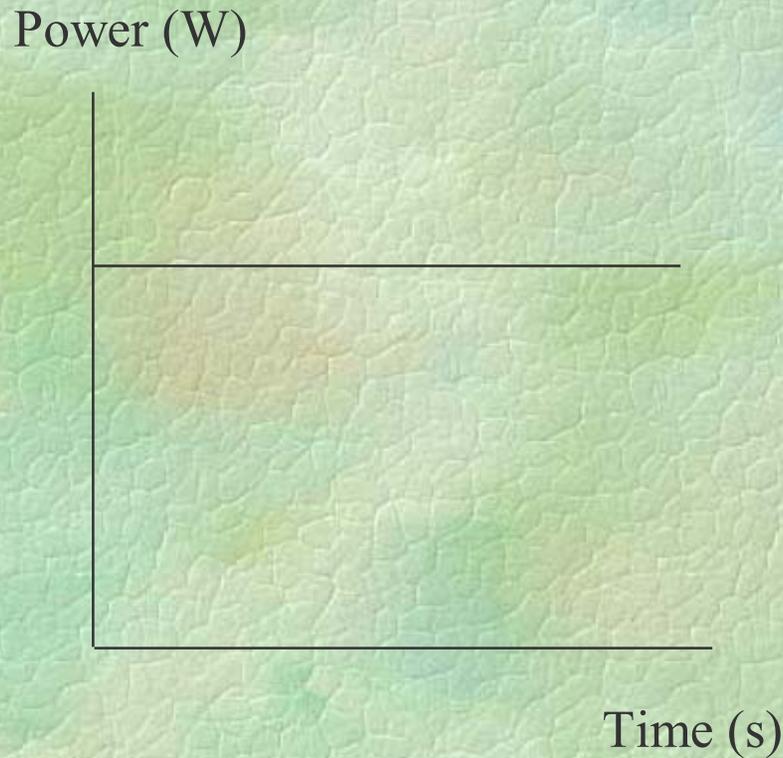
Laser Safety

Modes of Operation (cont'd)

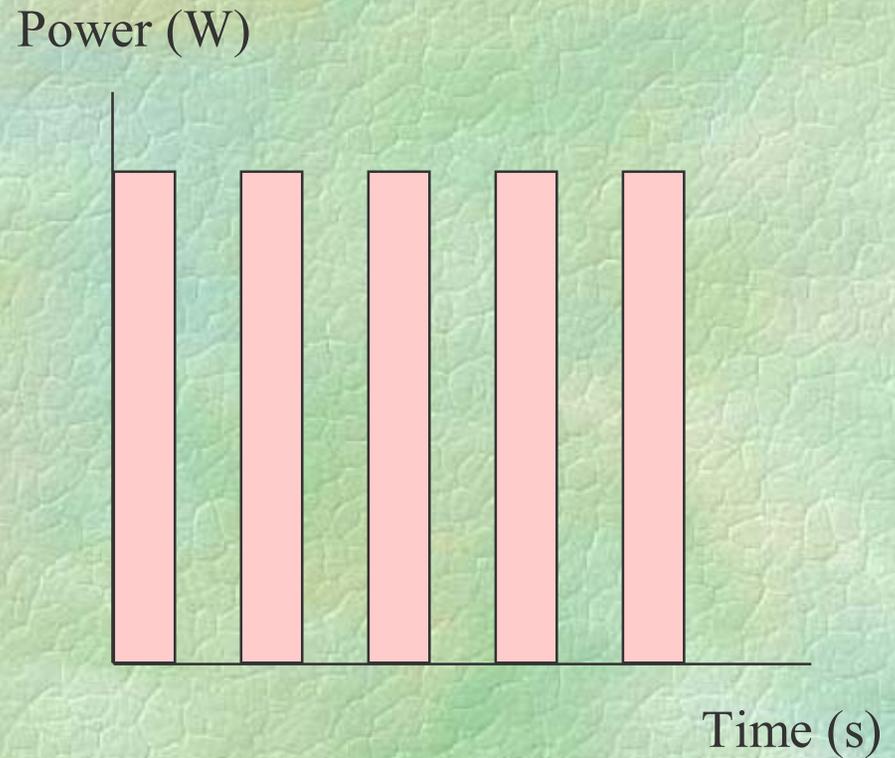


Laser Safety

Modes of Operation (cont'd)



CW Laser



Pulsed Laser

Laser Safety

Classification/Controls

- Class 1
- Class 2
- Class 3a
- Class 3b
- Class 4

Laser Safety

Classification/Controls (cont'd)

❖ Maximum Permissible Exposure (MPE) Limits

- Define the maximum amount of laser radiation to which nearly all personnel may be exposed without adverse effects
- Normally expressed in Joules/cm² (for pulsed lasers) or Watts/cm² (for CW lasers)
- Differ based on wavelength and exposure time

Laser Safety

Classification/Controls (cont'd)

• Class 1

- Laser devices not capable of emitting hazardous radiation under any viewing condition
- Do not exceed the accessible emission limit (AEL) for Class 1 lasers

Laser Safety

Classification/Controls (cont'd)

☞ Class 2

- Visible lasers that do not have enough power/energy to injure a person accidentally, but may cause injury if stared into. The natural aversion response will protect you from these lasers.

Laser Safety

Classification/Controls (cont'd)

• Class 2 lasers are

- Visible continuous wave lasers which can exceed the Class 1 AEL, but not exceeding 1mW.
- Visible repetitively pulsed lasers which can exceed the Class 1 AEL, but not exceeding the Class 1 AEL for a 0.25s exposure.

Laser Safety

Classification/Controls (cont'd)

☞ Class 3a

- Lasers which cannot cause injury if the beam is viewed with the naked eye. They can cause injury if the beam is focused or viewed through magnifying optics (binoculars).

Laser Safety

Classification/Controls (cont'd)

✿ Class 3a lasers

- have an accessible output power between 1 and 5 times the Class 1 AELs for wavelengths less than 400nm or greater than 700nm, or 5 times the Class 2 AELs for wavelengths between 400 and 700nm

Laser Safety

Classification/Controls (cont'd)

✿ Class 3b

- Lasers can produce accidental injuries if the beam is viewed directly or from a specular reflection, even momentarily.

Laser Safety

Classification/Controls (cont'd)

• Class 3b lasers are

- Mid/Far-IR and UV lasers which can't emit a radiant power $> 0.5 \text{ W}$ for $> 0.25\text{s}$ (cw), or cannot produce a radiant energy $> 0.125\text{J}$ within an exposure time $< 0.25\text{s}$ (pulsed).
- Visible CW or repetitively pulsed lasers which produce radiant power in excess of the Class 1 AEL for a 0.25s exposure time (1mW for a cw laser), but which cannot emit an average radiant power $> 0.5 \text{ W}$.

Laser Safety

Classification/Controls (cont'd)

• Class 3b lasers are

- Visible and near-IR pulsed lasers which cannot produce a radiant energy that exceeds $0.03C_A J$. (The limit at which the radiant exposure could produce a hazardous diffuse reflection).
- Near IR cw or pulsed lasers which cannot emit an average power $> 0.5 W$ for periods $> 0.25s$.

Laser Safety

Classification/Controls (cont'd)

☛ Class 4

- Lasers which can produce accidental injuries if the beam is viewed directly or from a specular reflection. They are also diffuse reflection hazards. Class 4 lasers are considered to be fire and skin hazards.

Laser Safety

Classification/Controls (cont'd)

☞ Class 4 lasers are

- UV and mid/far-IR lasers which emit an average accessible radiant power $> 0.5 \text{ W}$ for periods $> 0.25\text{s}$, or produce a radiant energy $> 0.125\text{J}$ within an exposure time $< 0.25\text{s}$.
- Visible and near-IR lasers which emit an average accessible radiant power $> 0.5 \text{ W}$ for periods $> 0.25\text{s}$, or produce radiant energy in excess of $0.03C_A\text{J}$ (that required to produce a diffuse reflection hazard).

Laser Safety

Classification/Controls (cont'd)

✿ Controls

- Class 1
 - None
- Class 2 and 3a
 - Personnel should be cautioned not to stare into laser or view with magnifying optics
- Class 3b
 - Eye protection used to prevent intra-beam viewing
 - Signs posted at entrance to area (indoor use)

Laser Safety

Classification/Controls (cont'd)

✿ Controls

- Class 4

- Danger signs at entrance; warning light
- Interlocks incorporated to entrance
- “Fail-safe” firing system; alarm system
- Backstop of earth, firebrick or other appropriate material
- Reflective surfaces removed; windows covered
- Operate remotely or enclose target area

Laser Safety Labeling

- ✿ All lasers built since 1976 require labeling in accordance with Title 21 CFR 1040
 - Class II (Caution)
 - Class IIIa (Caution/Danger)
 - Class IIIb (Danger)
 - Class IV (Danger)
- ✿ It is assumed that all lasers classified IAW 21 CFR 1040 meet the ANSI Z136.1 classifications

Laser Safety

Labeling (cont'd)

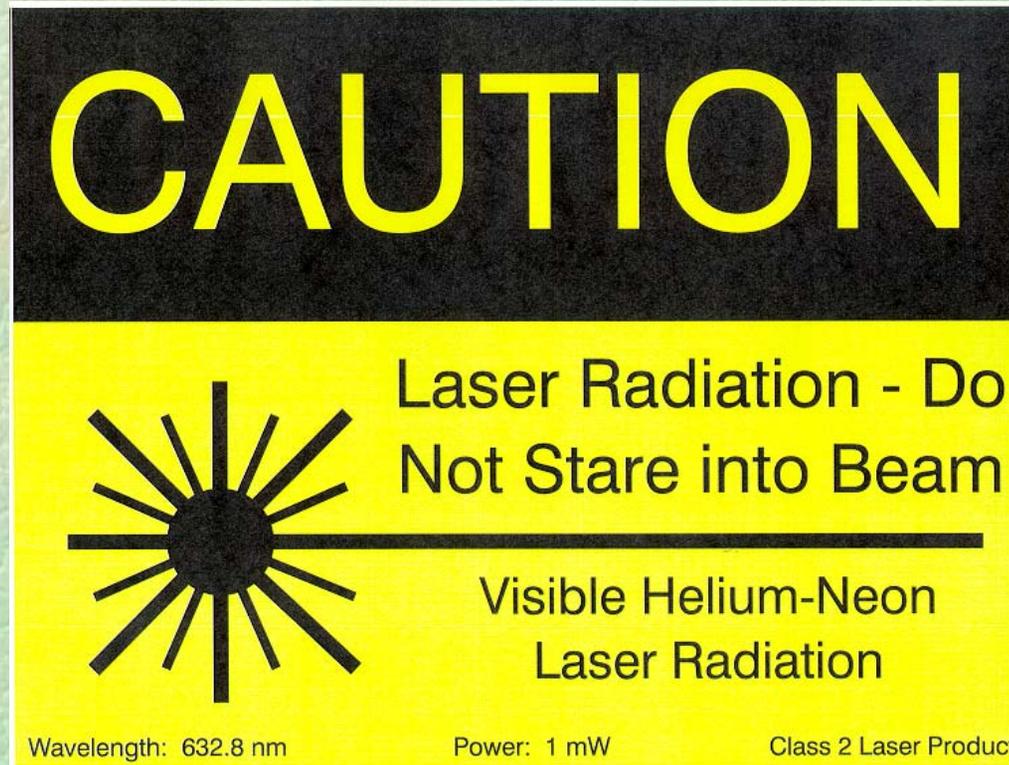
- ❖ Class I lasers are exempt from labeling except when it contains an embedded class IIIb or IV laser.

DANGER

**Laser Radiation When Open and
Interlock Defeated, Avoid Eye or
Skin Exposure to Scattered Radiation.**

Laser Safety Labeling (cont'd)

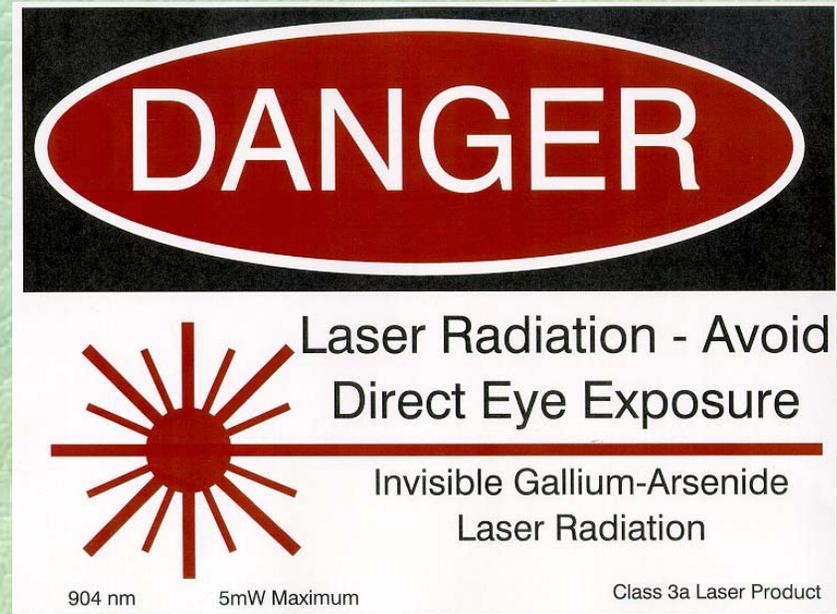
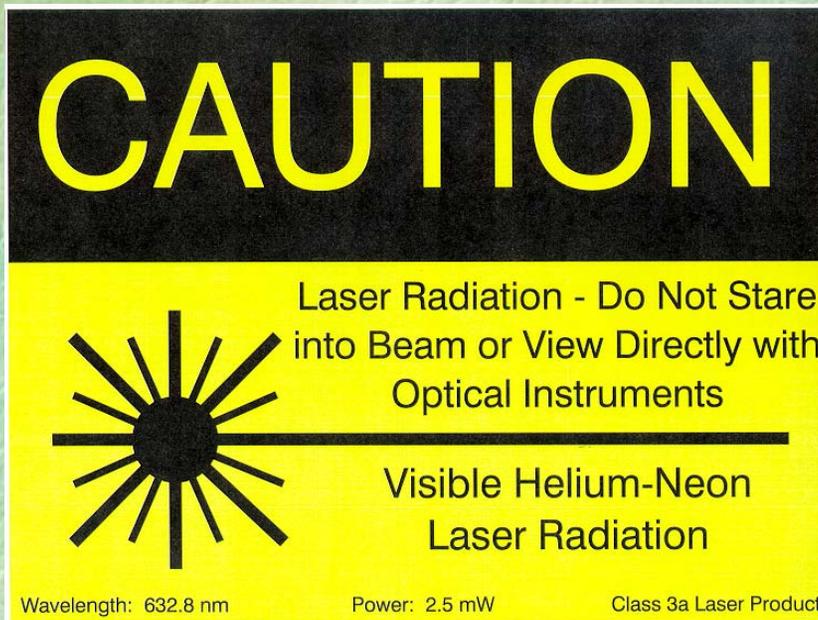
☛ Sample Class 2 Warning Label:



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Laser Safety Labeling (cont'd)

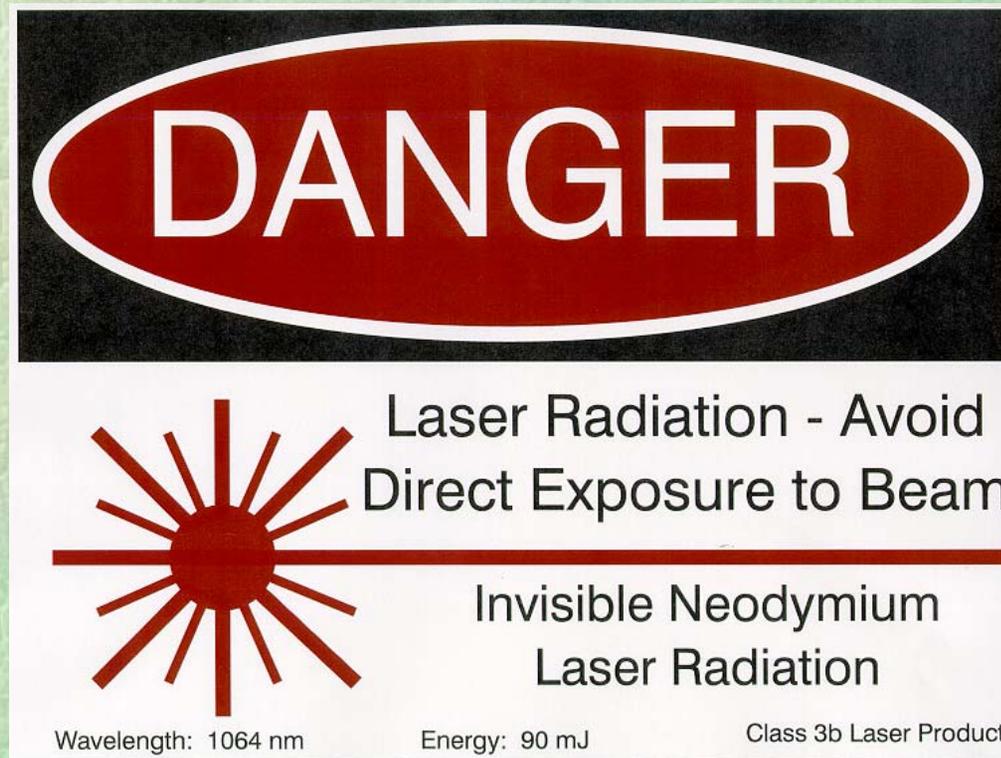
Sample Class 3a Warning Labels:



Laser Safety

Labeling (cont'd)

✿ Sample Class 3b Warning Label:



Laser Safety

Labeling (cont'd)

✿ Sample Class 4 Warning Label:



Laser Safety

Labeling (cont'd)

- ❖ Exempt lasers do not require labeling IAW 21 CFR 1040
- ❖ DOD may grant exemptions if the laser is
 - unable to meet Federal Standards and maintain mission effectiveness
 - used exclusively by DOD components
 - designed for actual combat, combat training, or are otherwise protected for national security purposes

Laser Safety

Labeling (cont'd)

- ❧ Exempt lasers should meet as many requirements of 21 CFR 1040 as possible and MIL-STD-1425A
- ❧ Labeled with DA Label 168:

Caution

This electronic product has been exempted from FDA radiation safety performance standards prescribed in Title 21, Code of Federal Regulations, Chapter I, Subchapter J, pursuant to Exemption No. 76EL-01 DOD issued on 26 July 1976. This product should not be used without adequate protective devices or procedures.

Laser Safety

Labeling (cont'd)

- ❖ Lasers that are granted an exemption by the DOD are classified in accordance with ANSI Z136.1

Laser Safety

Laser Bioeffects

❧ Laser injuries fall into two major categories:

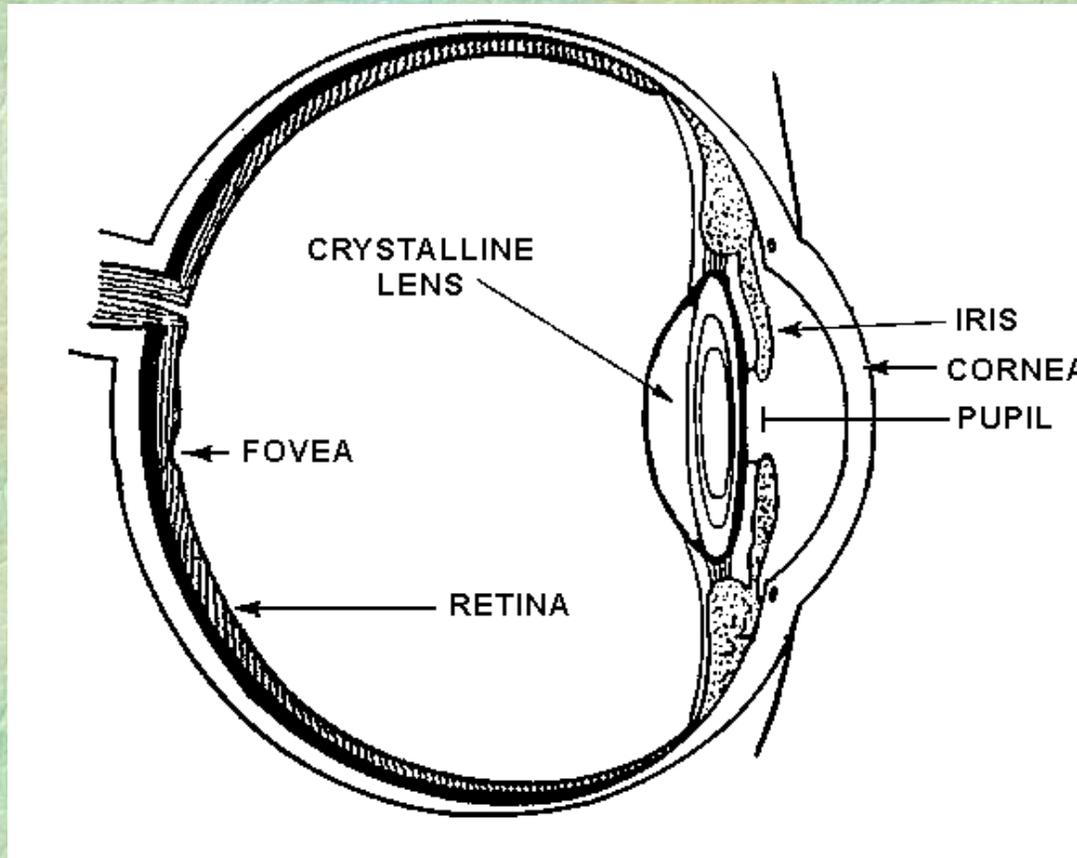
Eye Injuries

Skin Injuries

❧ The amount of energy absorbed depends upon the wavelength and the beam intensity

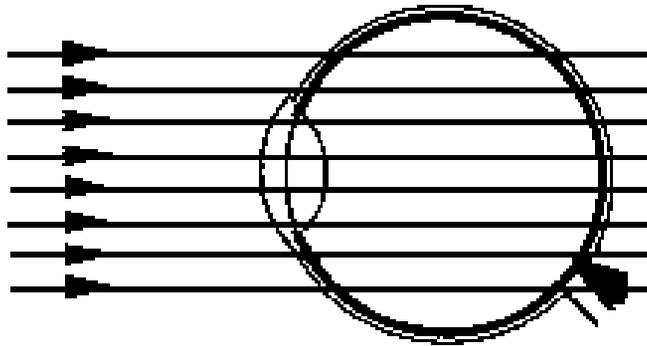
Laser Safety

Laser Bioeffects (cont'd)

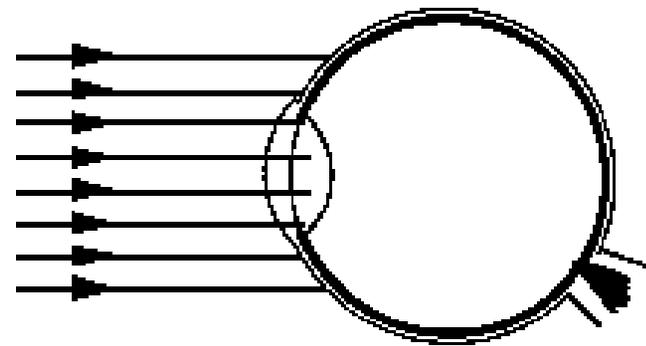


Laser Safety

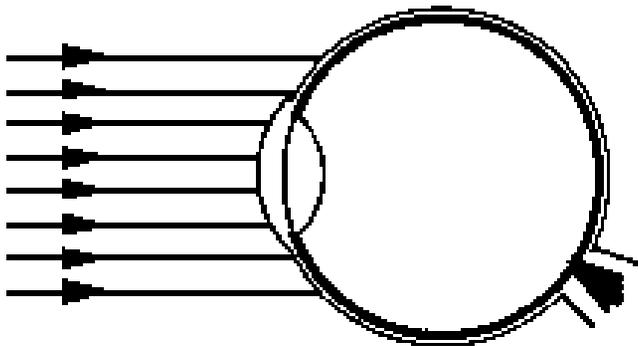
Laser Bioeffects (cont'd)



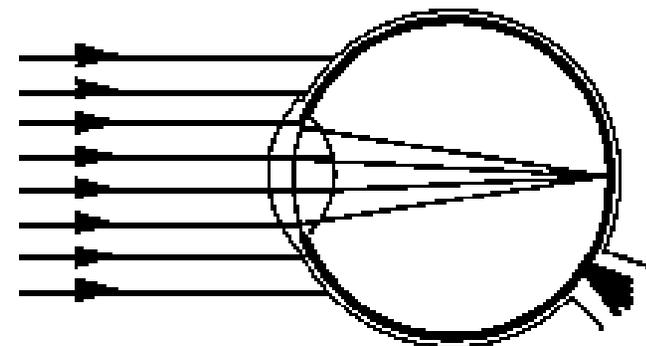
Microwaves and Gamma Rays



Near-Ultraviolet



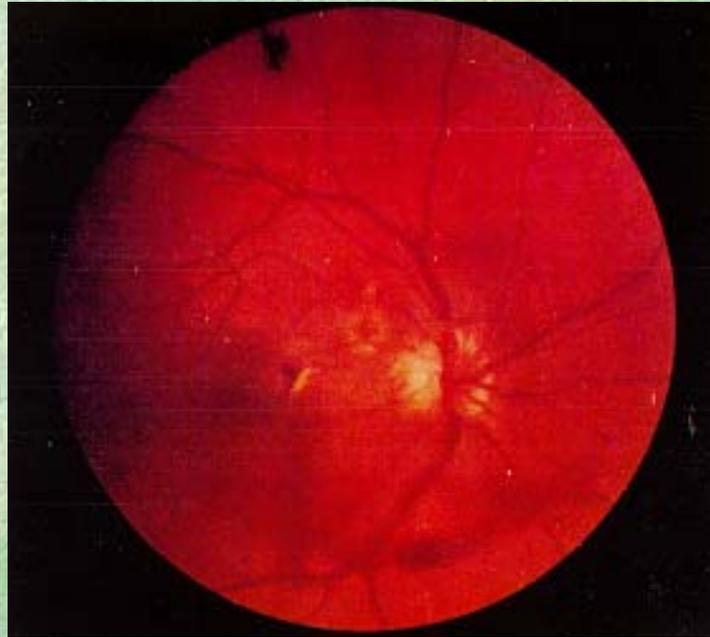
Far-Ultraviolet and Far-Infrared



Visible and Near-Infrared

Laser Safety

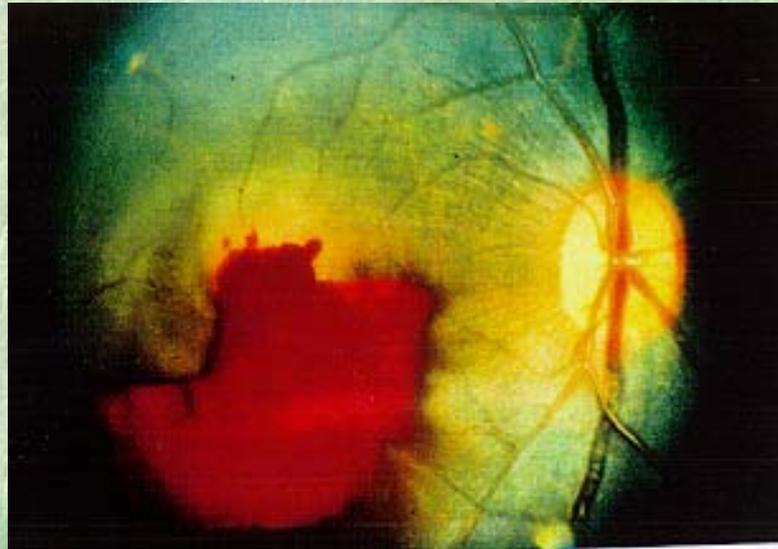
Laser Bioeffects (cont'd)



Subretinal Hemorrhage

Laser Safety

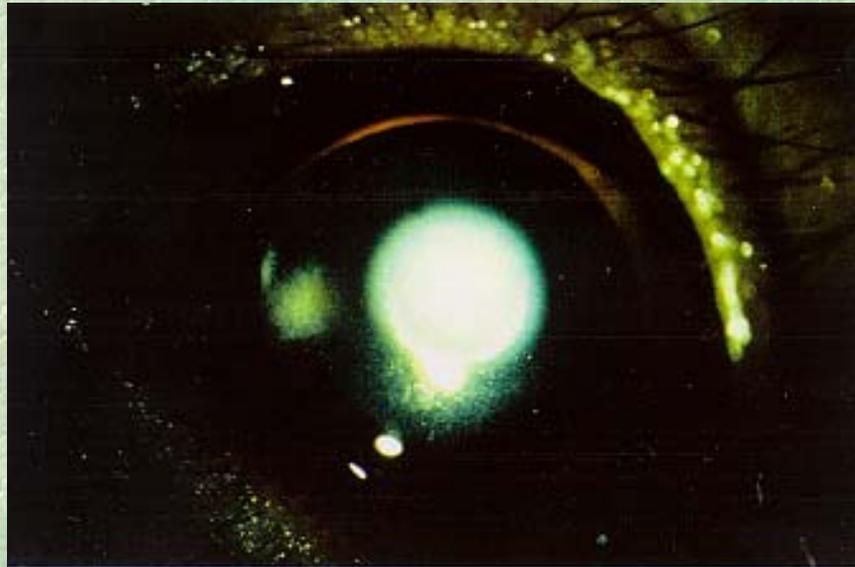
Laser Bioeffects (cont'd)



Profuse hemorrhage into the vitreous

Laser Safety

Laser Bioeffects (cont'd)



Corneal burns from far-infrared radiation

Laser Safety

Laser Bioeffects (cont'd)



Multiple laser burns w/ minimal hemorrhage

Laser Safety

Laser Bioeffects (cont'd)

- ❖ Due to the fact that a laser's energy is focused over a small area, significant localized injuries may occur
- ❖ Adverse thermal effects to skin vary from mild reddening to blistering and charring
- ❖ Avoid skin exposure to class 3 and 4 lasers

Laser Safety

Laser Bioeffects (cont'd)

✿ Extent of injury depends upon:

- wavelength
- energy/power output
- pulse duration and pulse repetition frequency
- size of the irradiated area
- duration of the exposure

Laser Safety

Medical Surveillance

- ✿ Requirements established by DA Surgeon General in a memorandum dated 11 April 1994
- ✿ RPO/LSO is responsible to assign workers to one of two categories:
 - Laser Workers
 - Incidental Laser Personnel

Laser Safety

Medical Surveillance (cont'd)

Laser Worker:

Individuals who routinely work in laser environments. These individuals are ordinarily protected by engineering controls, administrative procedures, and/or personal protective equipment

Examples: R&D personnel, maintenance personnel, system training personnel, and personnel using lasers for medical treatment

Laser Safety

Medical Surveillance (cont'd)

Incidental Laser Personnel:

Individuals working in a laser area whose work makes it unlikely that they will be exposed to laser energy sufficient to damage their eyes or skin

Examples: military personnel on field exercises, custodial personnel, clerical and supervisory personnel not working directly with laser devices

Laser Safety

Medical Surveillance (cont'd)

✿ Types of Examinations:

- Preplacement
- Termination
- Immediate

Laser Safety

Medical Surveillance (cont'd)

- ❖ All personnel who work with class 3b and 4 lasers (in either category) require preplacement and termination exams
 - Incidental laser personnel: visual acuity only
 - Laser worker: ocular history, visual acuity, color recognition, central visual fields and macular function (Amsler Grid)
- ❖ If findings, conduct Diagnostic Examination

Laser Safety

Medical Surveillance (cont'd)

- ❖ Immediate examinations are administered when there is a known or suspected laser overexposure
- ❖ Performed within 24 hours or as soon as possible after the suspected overexposure is reported

Laser Safety

Medical Surveillance (cont'd)

✿ Immediate examination protocol:

- Ocular history
- Visual Acuity
- Test for macular function (Amsler Grid)
- Slit lamp biomicroscope exam
- Ocular fundus evaluation (to include photography or other recording method)

Laser Safety

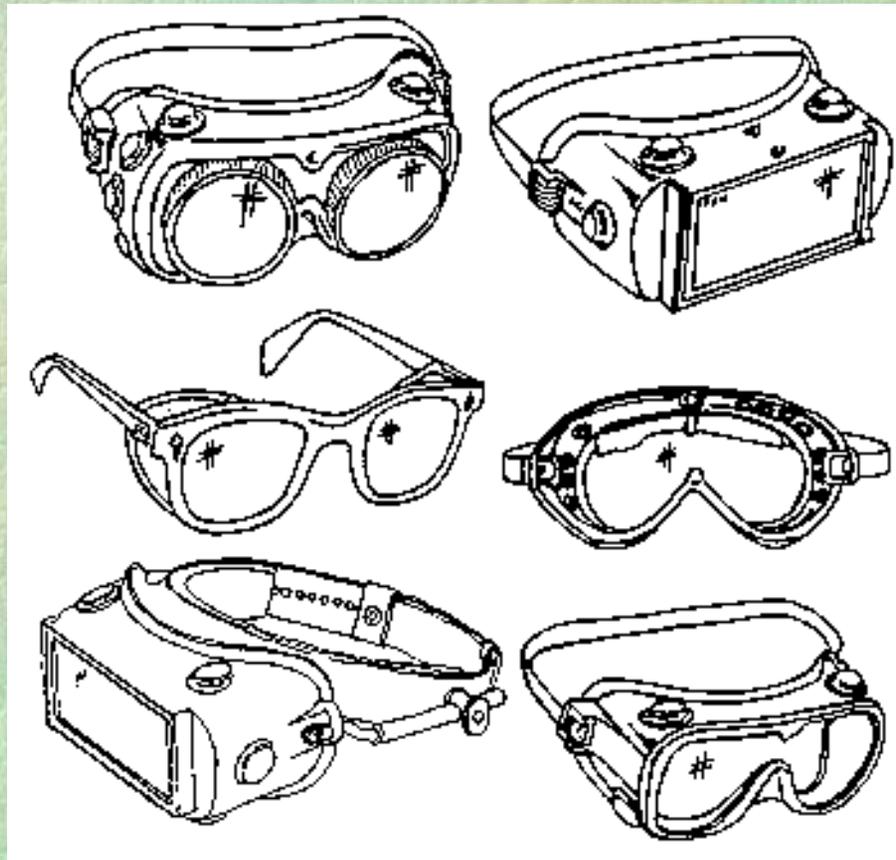
Medical Surveillance (cont'd)

❧ Overexposure reporting

- Contact installation/SRPO
- Contact USACHPPM Laser/Optical Program
- Contact laser eye injury hotline for assistance

Laser Safety

Laser Eye Protection



Laser Safety

Laser Eye Protection (cont'd)

• Effects used to filter out laser wavelengths:

- Selective spectral absorption by glass or plastic
- Selective reflection from coatings on glass or plastic

Laser Safety

Laser Eye Protection (cont'd)

✿ Glass absorbing filters

- Advantages: more effective in resisting damage from wear and from very intense laser sources
- Disadvantages: Poor impact resistance

Laser Safety

Laser Eye Protection (cont'd)

☞ Plastic absorbing filters

- Advantages: greater impact resistance, lightweight, easily molded into curved shapes
- Disadvantages: more easily scratched, quality control is difficult, organic dyes are more affected by heat and UV and may saturate or bleach under Q-switched laser radiation

Laser Safety

Laser Eye Protection (cont'd)

☞ Reflective Glass or Plastic:

- Advantages: Designed to selectively reflect a given wavelength while transmitting as much visible light as possible
- Disadvantages: Angular dependence of the spectral attenuation factor prohibits their use in goggle form

Laser Safety

Laser Eye Protection (cont'd)

✿ Factors to consider when choosing eyewear:

- Wavelength(s) to be protected against
- Maximum viewing duration
- Laser beam irradiance/radiant exposure
- Optical density required
- Visible transmittance of eyewear
- Laser filter damage threshold
- Field of view provided by design

Laser Safety

Laser Eye Protection (cont'd)

✿ Factors to consider when choosing eyewear (cont'd):

- Curvature of lens design
- Availability of prescription lenses (or sufficient goggle size to wear glasses underneath)
- Comfort of design
- Ventilation ports
- Impact resistance

Laser Safety

Laser Eye Protection (cont'd)



Laser Safety

Laser Eye Protection (cont'd)



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Laser Safety

Laser Eye Protection (cont'd)



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Laser Safety

Laser Eye Protection (cont'd)



Laser Safety

Additional Hazards

- ❧ Atmospheric contamination
- ❧ Ultraviolet radiation
- ❧ Electrical hazards
- ❧ Cryogenic coolants
- ❧ X-rays

Laser Safety

High Intensity Optical Sources

- ✿ Arc lamps (carbon, mercury, xenon, etc.)
- ✿ Incandescent rated 400W or more
- ✿ Quartz lamps
- ✿ Searchlight lamps
- ✿ Lamps used as IR sources
- ✿ Solar simulators
- ✿ Arc welding equipment
- ✿ Germicidal lamps and other UV sources

Laser Safety

High Intensity Optical Sources (cont'd)

☞ Safety precautions

- Wear protective eyewear
- Stop viewing if causing eye discomfort
- Be alert (especially with UV and IR sources)
- Post warning signs in area

☞ If working with carbon arc equipment:

- turn on room ventilation and local exhaust fans
- Wear PPE for your skin and eyes

Laser Safety

High Intensity Optical Sources (cont'd)

❧ Radiation Protection Standards

- Use the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs) for exposure to optical radiation other than lasers.

Laser Safety

Overall Program Requirements

❧ Parties responsible for ensuring an adequate radiation protection program is established:

- Radiation Control Committee/Officer
- Installation/State Radiation Protection Officer
- Local RPO/LSO
- Laser Range Safety Officer

Laser Safety

Overall Program Requirements (cont'd)

✿ Requirements of NRPP:

- Ensure CHPPM evaluation completed
- Ensure personnel are informed of hazards
- Ensure SOPs are published and enforced
- Conduct periodic checks of safety devices
- Post all controlled areas as required
- Ensure alleged overexposures are reported
- Individuals designated to receive notice
- Comprehensive inventory is maintained

Laser Safety

Overall Program Requirements (cont'd)

☛ Local Office Requirements

- Post appropriate warning signs/notices
- Assure operators receive instruction/training
- Maintain a roster of authorized personnel
- Establish written SOPs and get approval
- Enforce SOPs
- Maintain a current laser inventory
- Report any laser incident/accident

Laser Safety

Overall Program Requirements (cont'd)

✿ Local Office Requirements (cont'd)

- Ensure workers attend annual briefings
- Assure copies of regs/SOPs are on site
- Provide laser protective eyewear when necessary

Laser Safety

Safety Practices/Precautions

☞ Indoor use

- Wear clothing free of reflective buttons, etc.
- Never leave an activated laser unattended
- Follow two-man rule for class 3b and 4 lasers
- Never direct beam at personnel
- Avoid aiming laser with the naked eye
- Work in areas of high general illumination
- Ensure eyewear provided adequate protection

Laser Safety

Safety Practices/Precautions (cont'd)

☛ Indoor use (cont'd)

- Use a backstop to terminate high energy beams
- Unused secondary beams will be capped or terminated
- Don't set up beam path at normal eye level
- Post warning signs at entrances (class 3/4)
- Have fire extinguishers accessible for laser that present a fire hazard

Laser Safety

Safety Practices/Precautions (cont'd)

✿ Indoor use of Class 4 lasers

- Safety interlocks at entrance to facility
- “Fail-safe” firing systems
- Alarm to indicate capacitor banks charging
- Operate laser remotely, if feasible
- Enclosure of the laser beam/target area in a “light tight” box

Laser Safety

Safety Practices/Precautions (cont'd)

✿ Maintenance

- Personnel must be specially trained
- Power should be turned off and capacitors “bled-off”
- Test laser systems only in controlled areas
- Wear protective eyewear as necessary
- Adhere to procedures in TM and precautions in TB 385-4

Laser Safety

Safety Practices/Precautions (cont'd)

✿ Outdoor use

- Never direct the laser at personnel
- Exclude unprotected personnel from beam path
- Tracking of nontarget vehicular traffic or aircraft shall be prohibited
- Clear target area of flat specular surfaces

Laser Safety

Safety Practices/Precautions (cont'd)

☛ Unit commander responsibilities

- Designate/train a Laser Range Safety Officer
- Develop an SOP for laser operations
- Instruct personnel prior to laser operations
- Require reporting of potential overexposures
- Control downrange area to prohibit entry of unauthorized personnel

Laser Safety

Safety Practices/Precautions (cont'd)

☛ LRSO responsibilities

- Become familiar with regulations/TMs, etc.
- Brief unit personnel
- Know firing positions, approved targets
- Ensure eyewear is worn when required
- Ensure compliance with SOP
- Maintain contact w/ downrange personnel
- Cease lasing operation if control of beam is lost

Laser Safety

Safety Practices/Precautions (cont'd)

❖ LRSO training/instruction must include:

- Principles of reflection/refraction of light
- Hazards of laser beams to humans
- Safety standards governing operational control procedures
- Preparation of range areas for laser use
- Understanding of the hazards of specific devices to be used and proper eyewear

Laser Safety

Safety Practices/Precautions (cont'd)

☛ Range control procedures

- Prevent intrabeam viewing by personnel
- Remove specular reflections downrange
- Fire only at designated diffuse targets
- Provide eyewear for personnel downrange
- Develop SOPs based on operating conditions
- Place warning signs

Laser Safety

Safety Practices/Precautions (cont'd)



Laser Safety

Safety Practices/Precautions (cont'd)

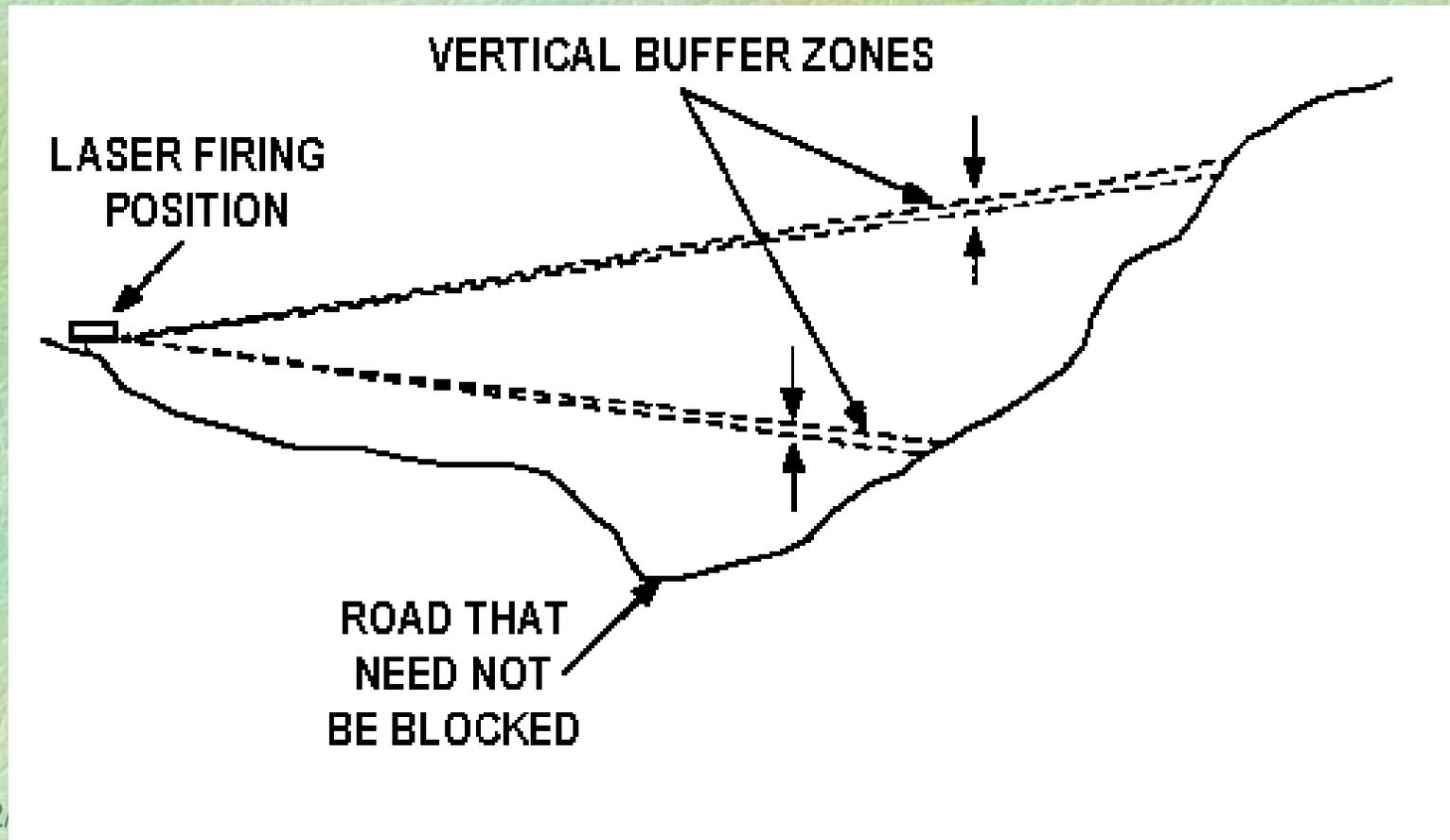
❧ Laser Surface Danger Zone

- Establish based on:
 - buffer zones required
 - Nominal Ocular Hazard Distance (NOHD)
 - specular/diffuse reflection hazard
 - available natural backstops

❧ Current surface danger zones provide required buffer zones for ground-to-ground operations

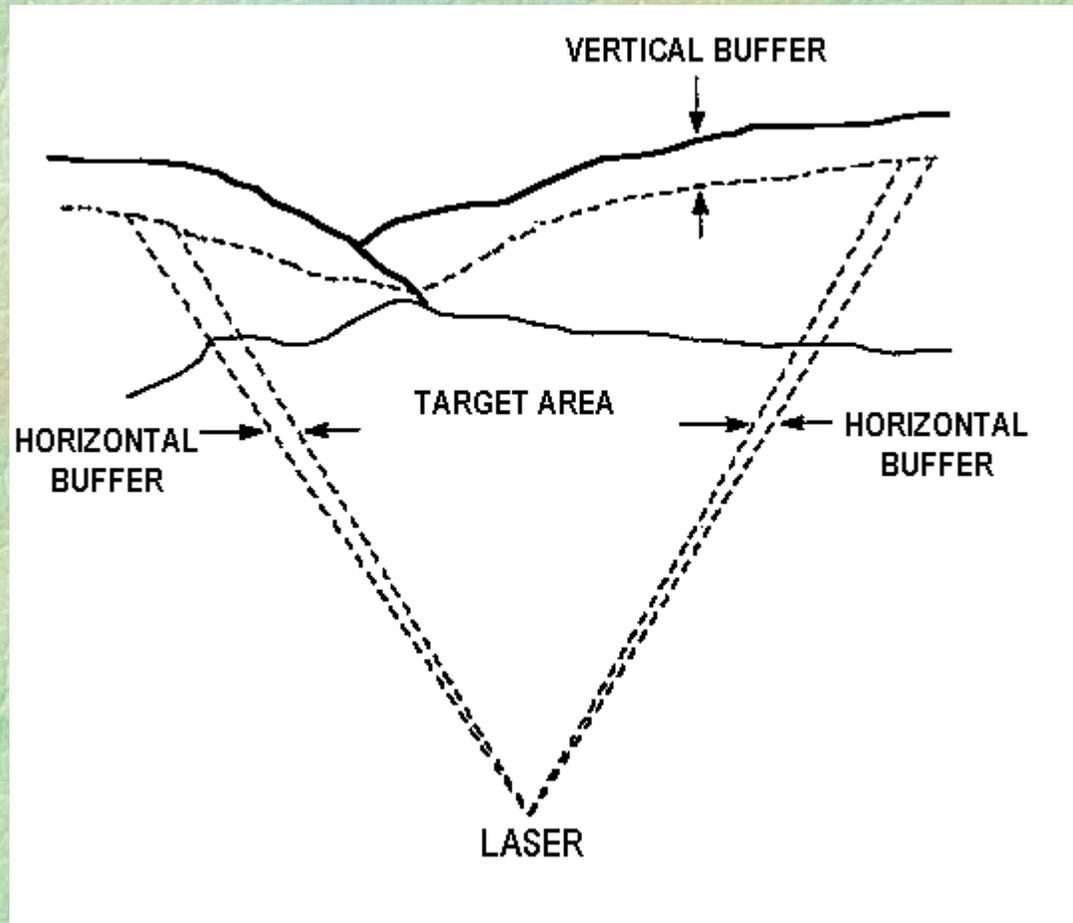
Laser Safety

Safety Practices/Precautions (cont'd)



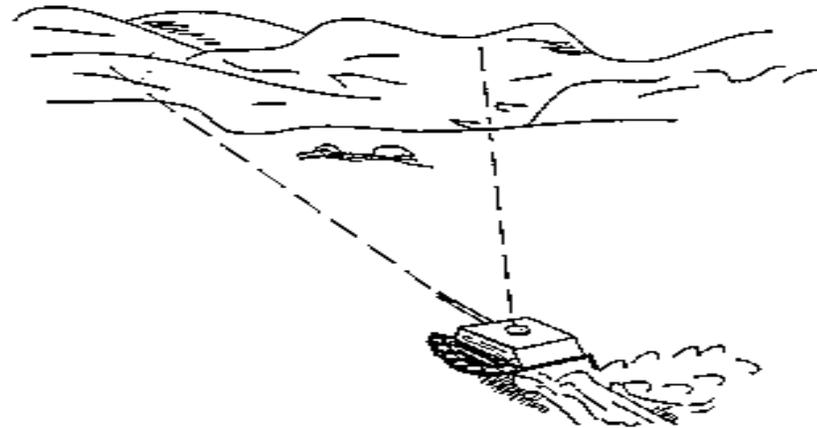
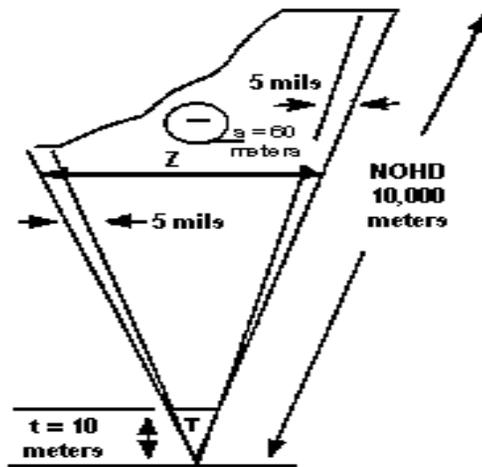
Laser Safety

Safety Practices/Precautions (cont'd)



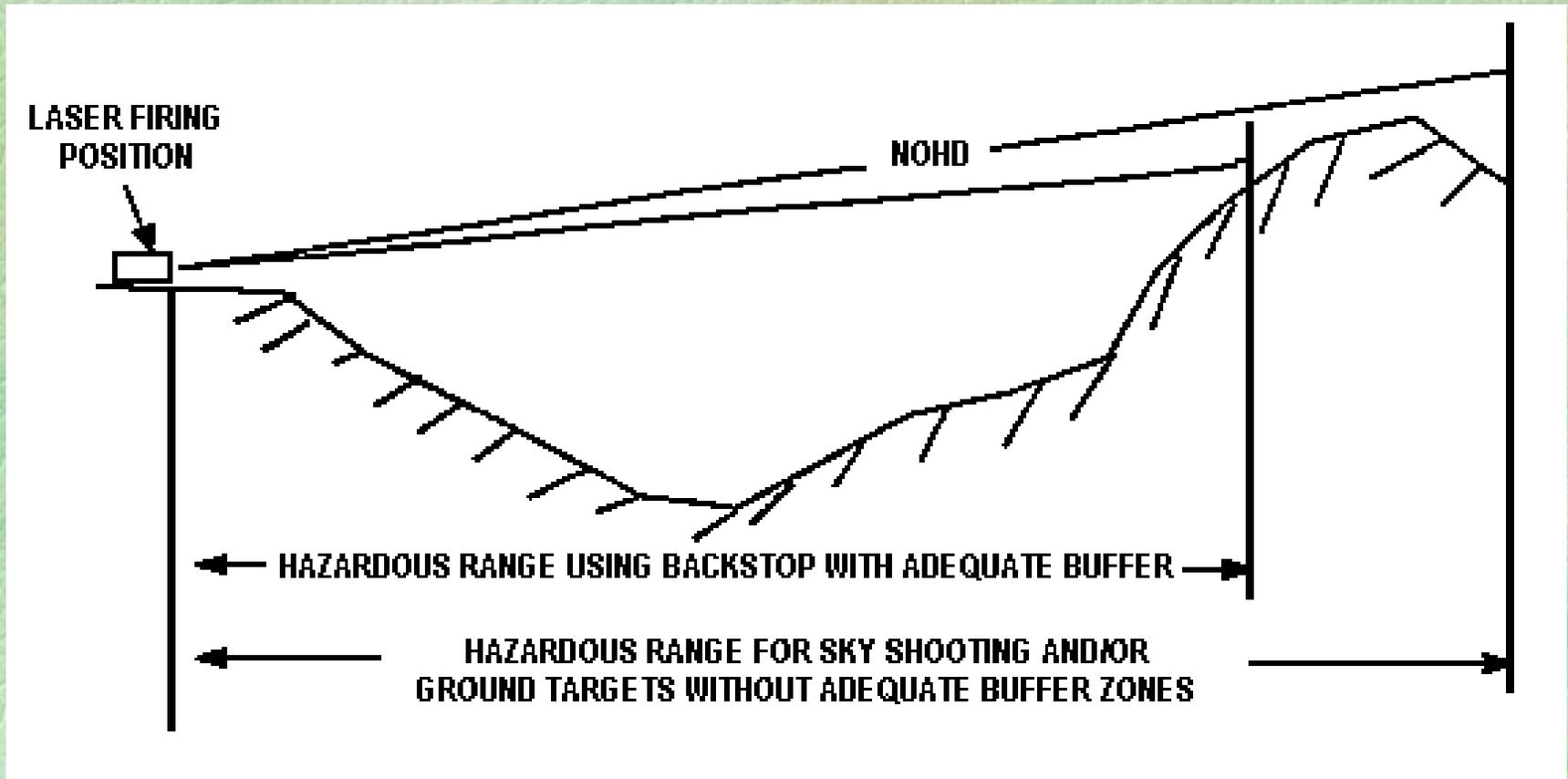
Laser Safety

Safety Practices/Precautions (cont'd)



Laser Safety

Safety Practices/Precautions (cont'd)



Laser Safety

Safety Practices/Precautions (cont'd)

❖ Operation outside range area

- Always cover exit port when not in use
- Maintenance in controlled area as discussed
- Pre-fire checks allowed in controlled area provided an adequate beam stop is present

Laser Safety

Accident Reporting Procedures

- ✿ Disconnect the power from the equipment
- ✿ Do not alter the configuration
- ✿ Receive written statements from anyone present
- ✿ Get copies of maintenance/operational logbook and any other data
- ✿ Notify the chain of command

Laser Safety

Accident Reporting Procedures (cont'd)

- ❖ Ensure individual receives medical exam within 24 hours
- ❖ Notify the RCO within 24 hours
- ❖ Notify the USACHPPM Laser/Optical Program within 24 hours

For medical assistance, call the Laser Eye Injury Hotline at 800-473-3549

Laser Safety

Accident Reporting Procedures (cont'd)

Information to be assembled

- Location of laser range and name of LSO
- Identity of injured individual
- Date and time of accident
- Type of laser/operating parameters
- Approximate distance from the source
- Intrabeam viewing or reflection
- Optical instruments involved (if any)

Laser Safety

Accident Reporting Procedures (cont'd)

- Information to be assembled (cont'd)
 - Type of eyewear worn (or reason for not wearing eyewear)
 - Brief description of the incident
 - Identity of attending physician
 - Details of immediate medical findings

Laser Safety

References

- ❖ ANSI Z136.1-1993, American National Standard for Safe Use of Lasers
- ❖ AR 40-5, Preventive Medicine
- ❖ AR 385-63, Policies and Procedures for Firing Ammunition for Training, Target Practice, and Combat

Laser Safety

References (cont'd)

- ❖ DODI 6055.11, Protection of DoD Personnel from Exposure to Radiofrequency Radiation and Military Exempt Lasers
- ❖ FM 8-50, Prevention and Medical Management of Laser Injuries
- ❖ MIL-HDBK-828, Laser Range Safety
- ❖ MIL-STD-1425A, Safety Design Requirements for Military Lasers and Associated Support Equipment

Laser Safety

References (cont'd)

- ❧ TB 43-0133, Hazard Criteria for CECOM Radiofrequency and Optical Radiation Producing Equipment
- ❧ TB MED 524, Control of Hazards to Health from Laser Radiation
- ❧ Title 21, Code of Federal Regulations, Part 1040, Performance Standards for Light-Emitting Products