Introduction to Laser Safety

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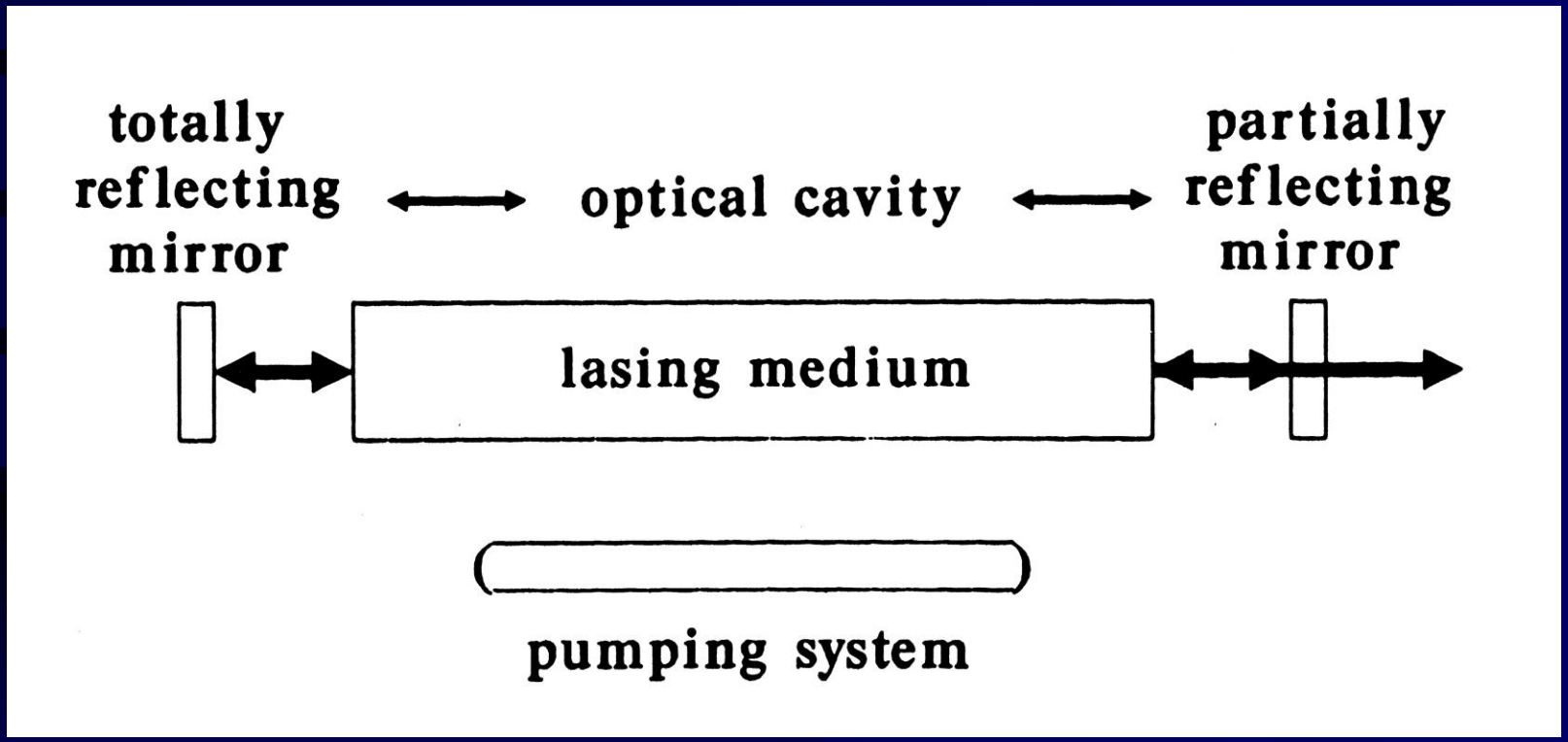
Includes slides from University of Illinois at Urbana-Champaign

Laser Basics - Laser Hazard

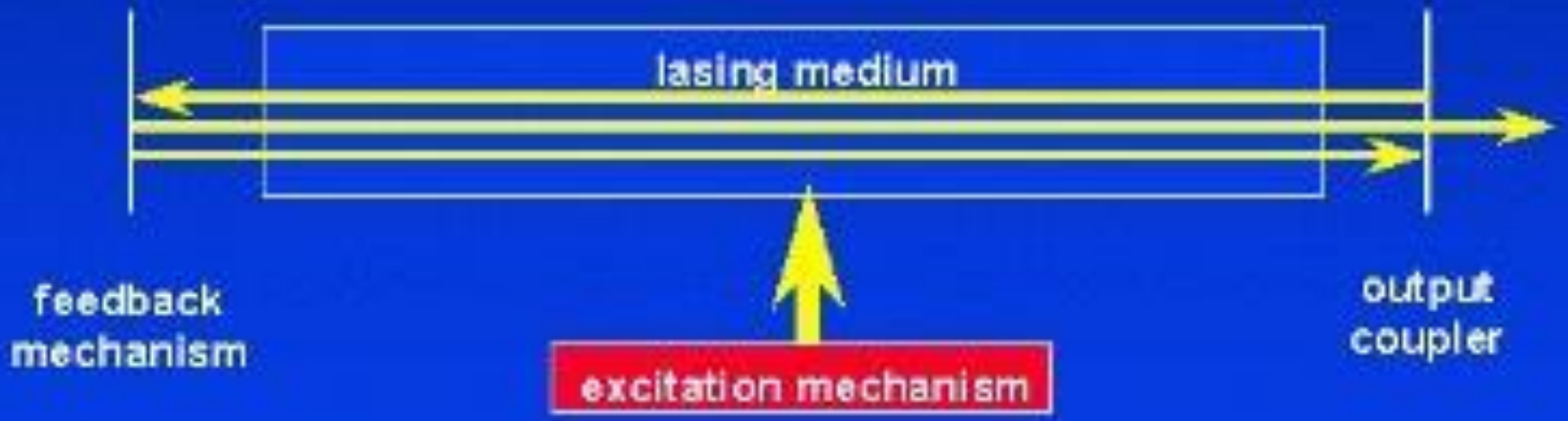
- Laser light differs from ordinary light in 3 ways:
  - Monochromatic
  - Directional
  - Coherent
- Lasers can pose more of a hazard than ordinary light because they can focus a lot of energy onto a small area

Laser Components



Laser Basics - Design

- Laser Design
  - Lasing Medium (gas, liquid, solid, semiconductor)
  - Excitation Mechanism (power supply, flashlamp, laser)
  - Feedback Mechanism (mirrors)
  - Output coupler (semi-transparent mirror)



Laser Basics - Types of Lasers

- Different lasing media
  - Gas, liquid, solid, semi-conductor, dye
- Continuous wave (CW), Pulsed, Q-switched

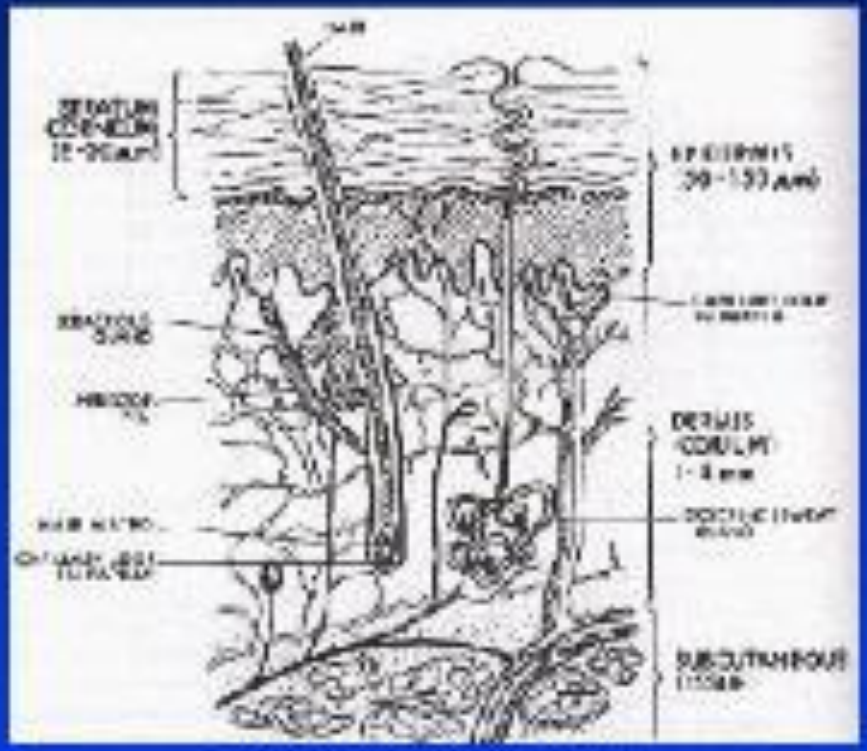
Laser Bioeffects - EM Spectrum

- Optical portion of Electromagnetic Spectrum:
  - Infrared (780 nm - 1 mm)
    - Far-IR (IR-B, IR-C) (1400 nm - 1 mm)
    - Near-IR (IR-A) (780 nm - 1400 nm)
  - Visible (400 nm - 780 nm)
  - Ultraviolet (200 nm - 400 nm)
    - Far-UV (UV-B, UV-C) (200 nm - 315 nm)
    - Near-UV (UV-A) (315 nm - 400 nm)

Laser Bioeffects - Damage

- Primary sites of damage
  - eyes
  - skin
- Laser beam damage can be
  - thermal (heat)
  - acoustic
  - photochemical

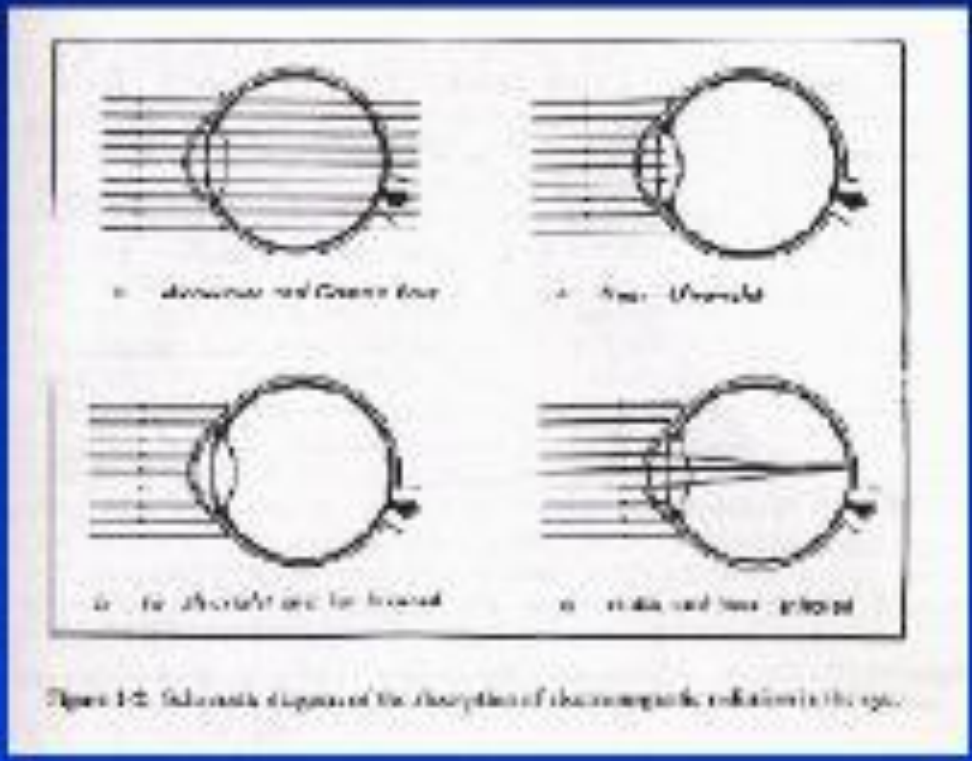
Laser Bioeffects - Skin

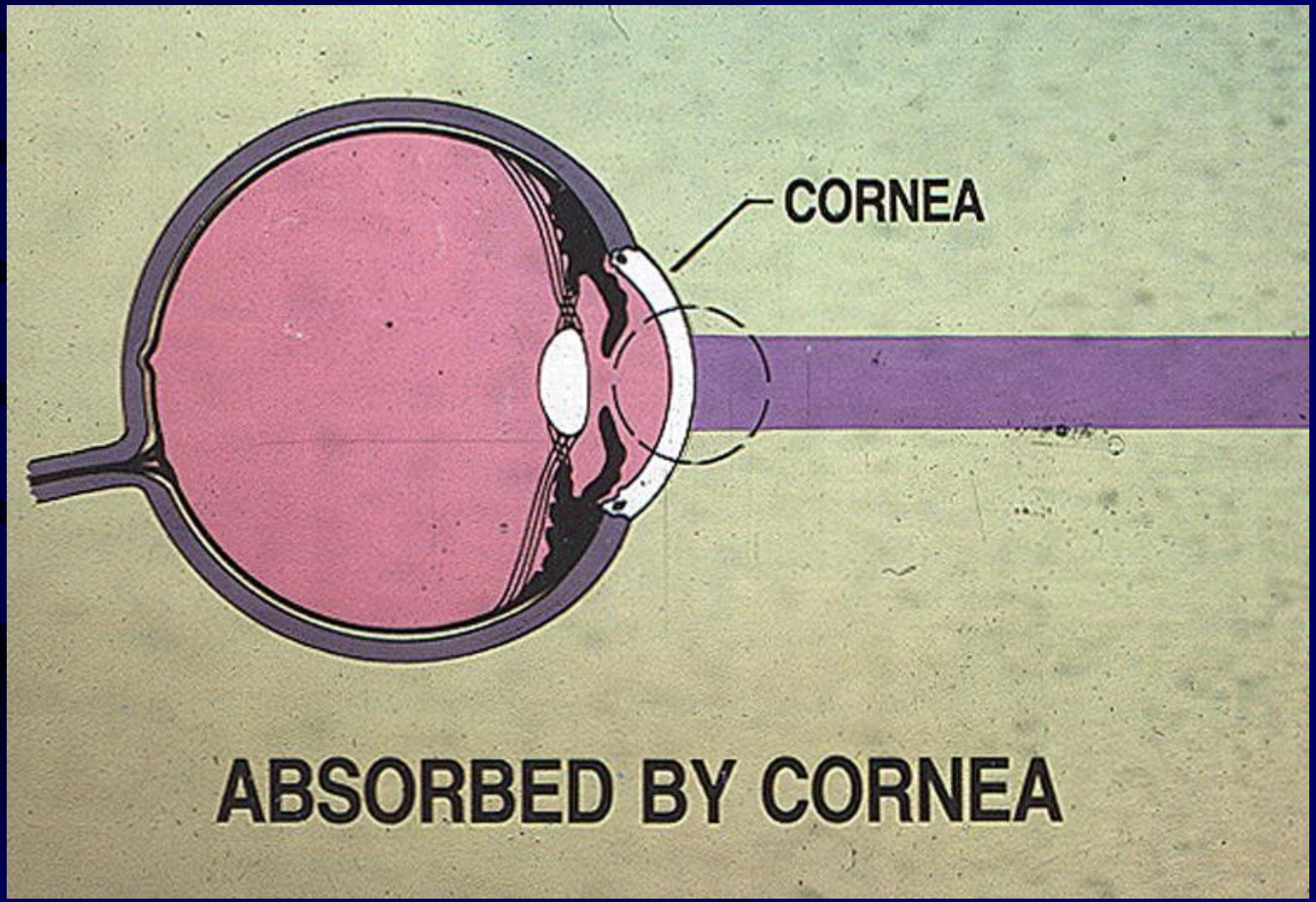


- Skin Sensitivity
  - Dermis (IR-A)
  - Epidermis (UV-B, UV-C)

Laser Bioeffects - Eye

- **Eye Sensitivity**
  - Retina (visible, IR-A)
  - Lens (UV-A)
  - Cornea (UV-B, UV-C, IR-B, IR-C)





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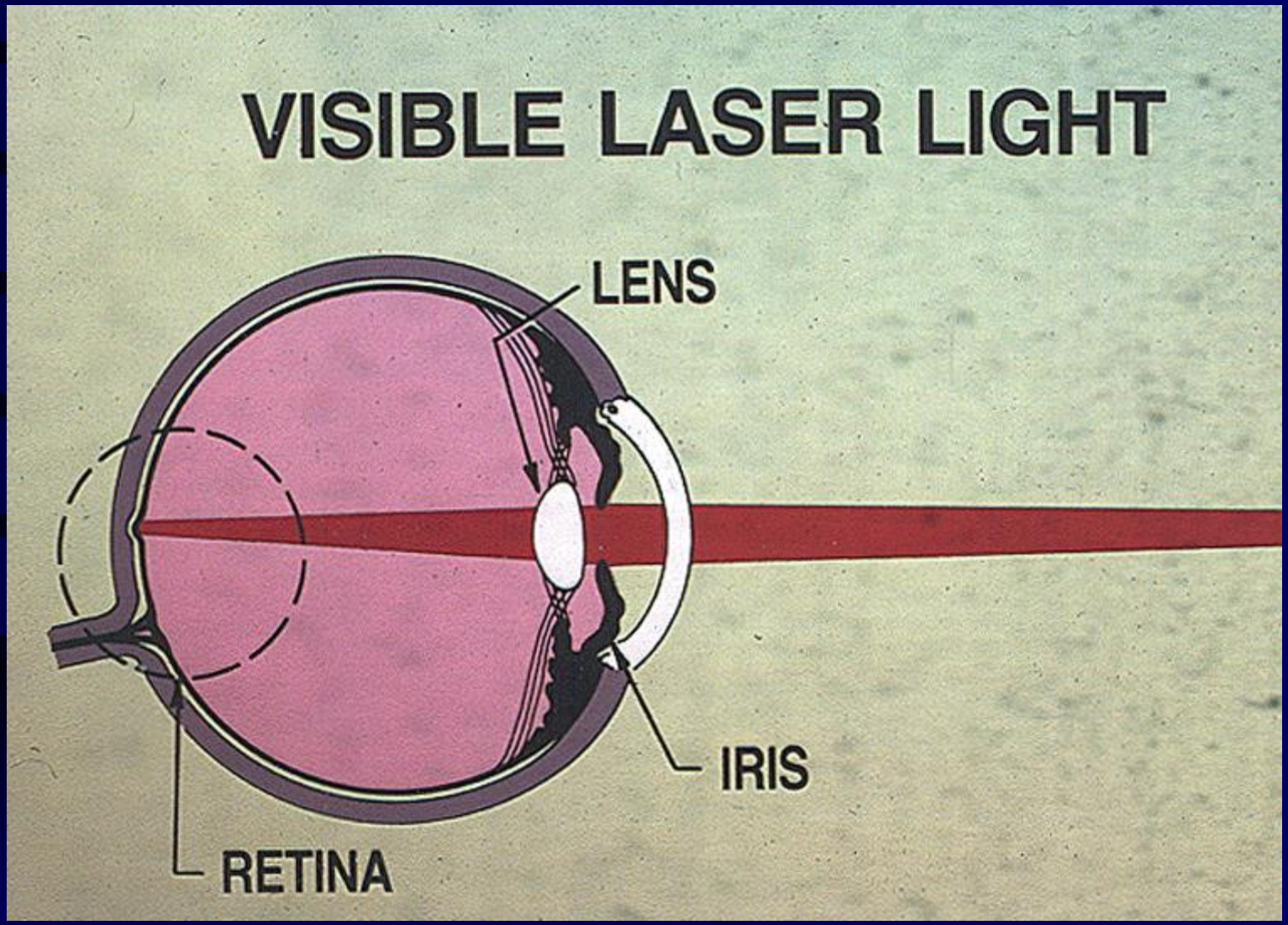

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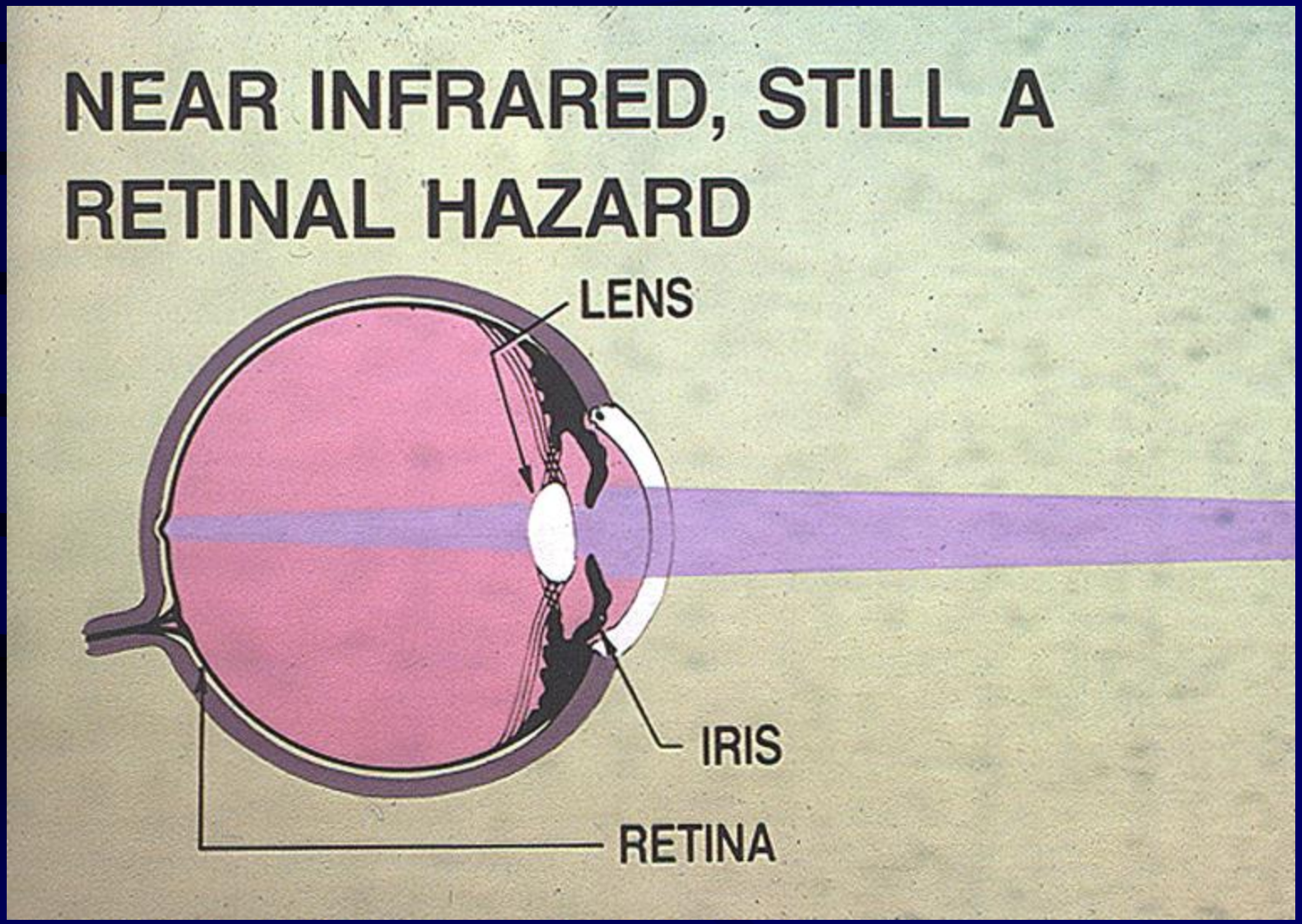

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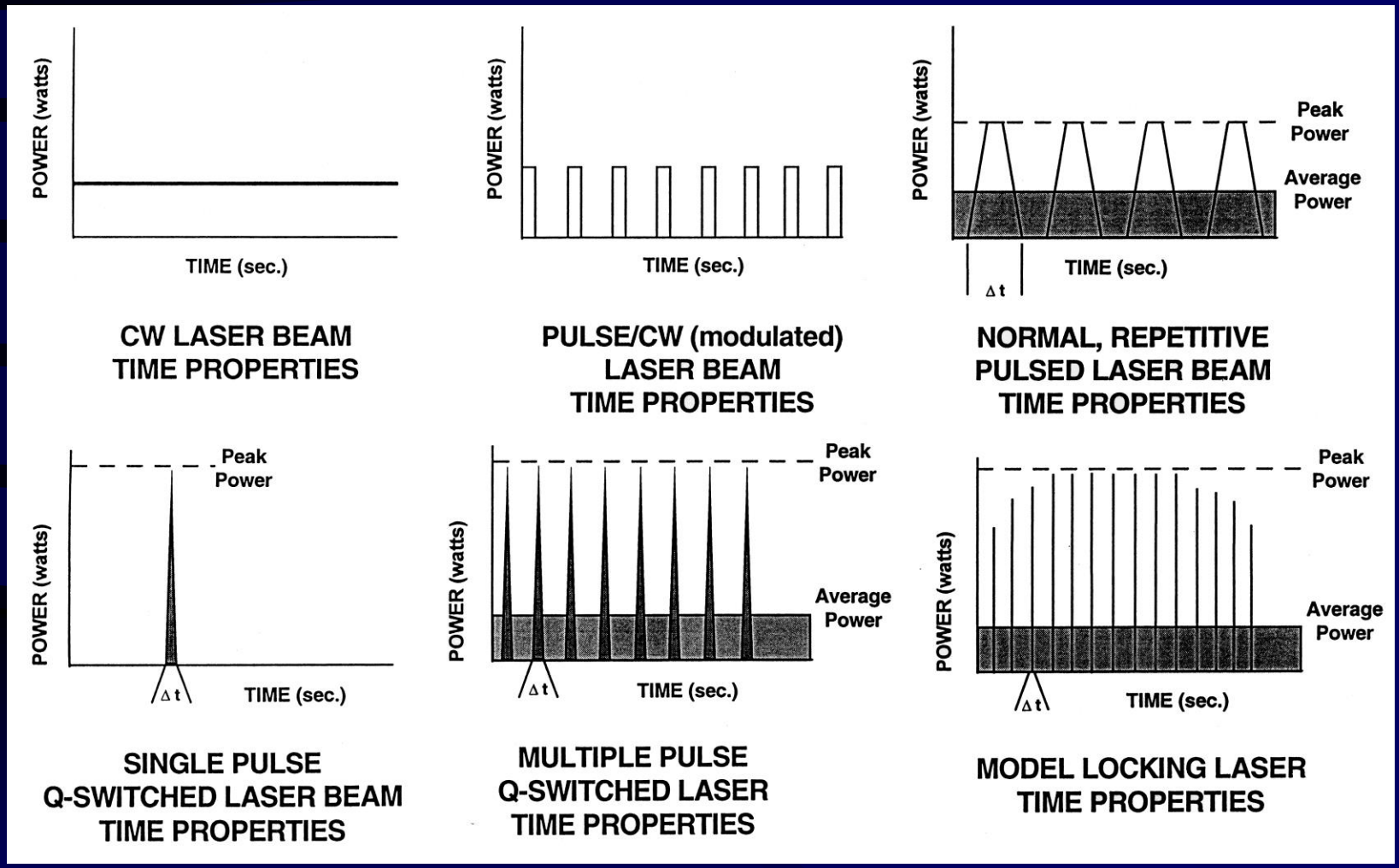
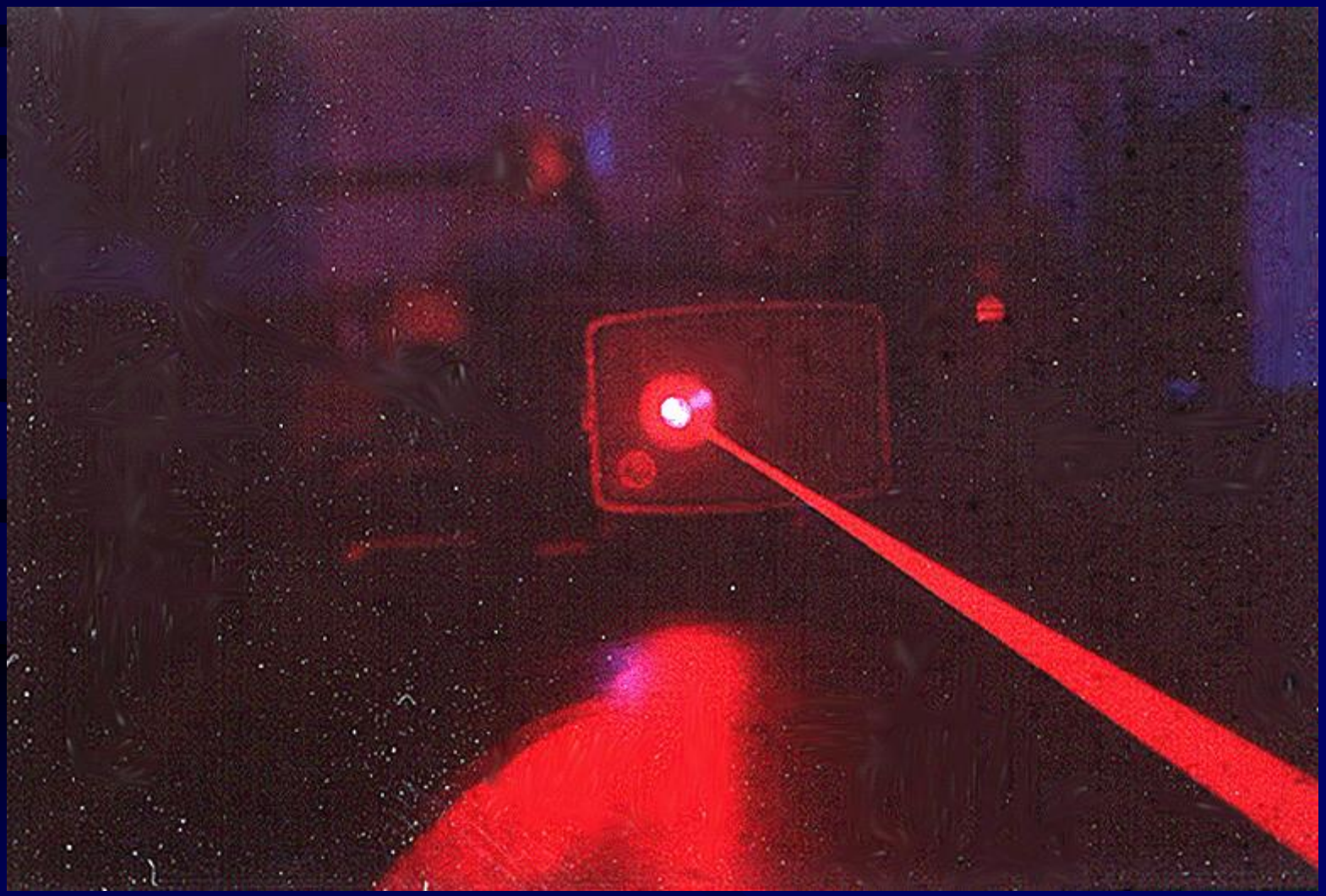
Laser Exposure Limits - Terms

- **MPE (Maximum Permissible Exposure)**
  - the highest laser energy to which the eye or skin can be exposed for a given laser
- **NHZ (Nominal Hazard Zone)**
  - area within which the MPE is equalled or exceeded
- **NOHD (Nominal Ocular Hazard Distance)**
  - distance along the laser beam axis beyond which is acceptable for eye exposure

Continuous vs. Pulsed Lasers



Thinner pulses give higher peaks for same average Power.



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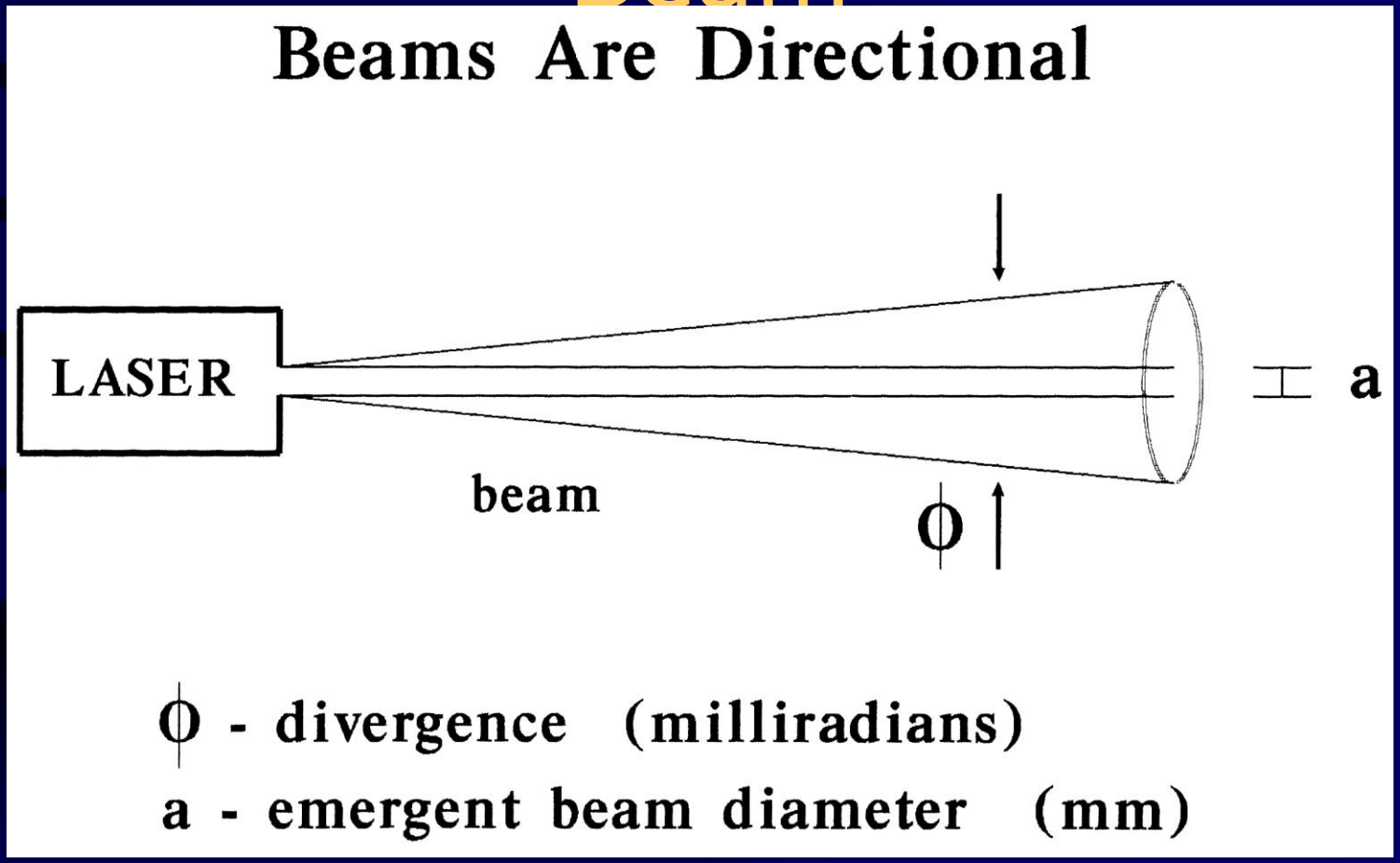
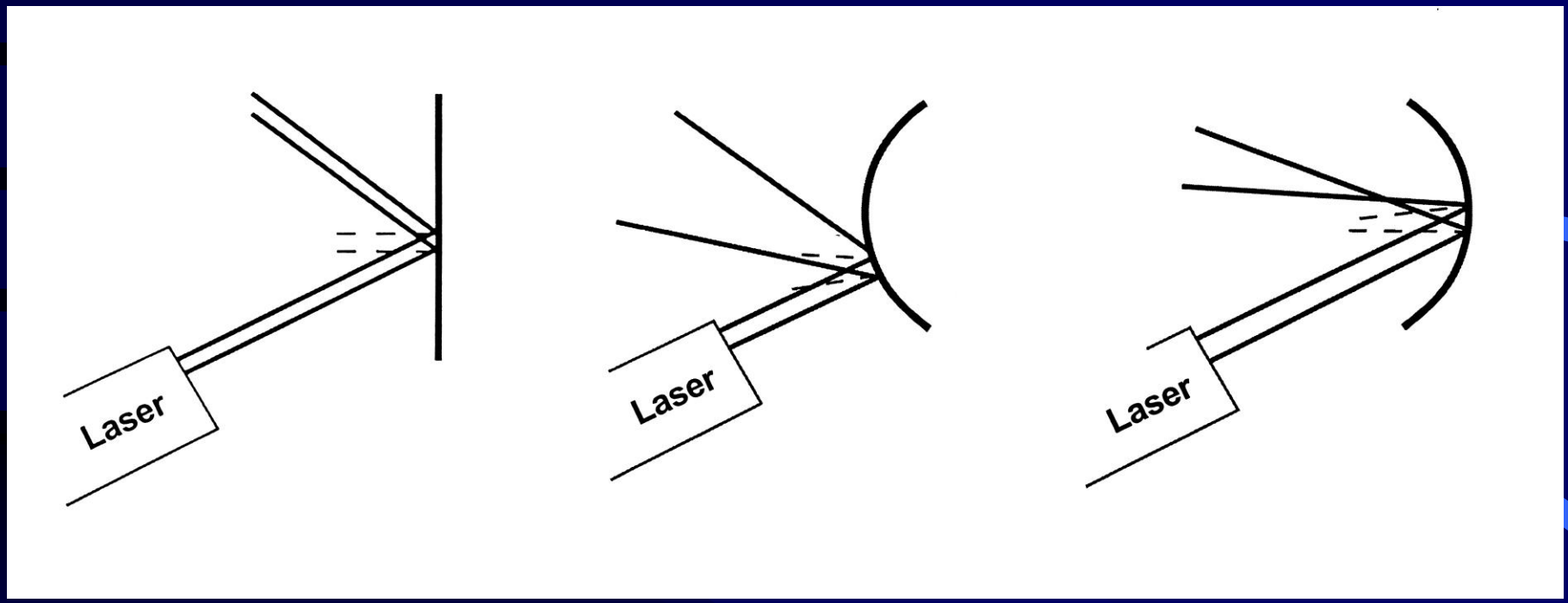
Divergence of the Laser Beam



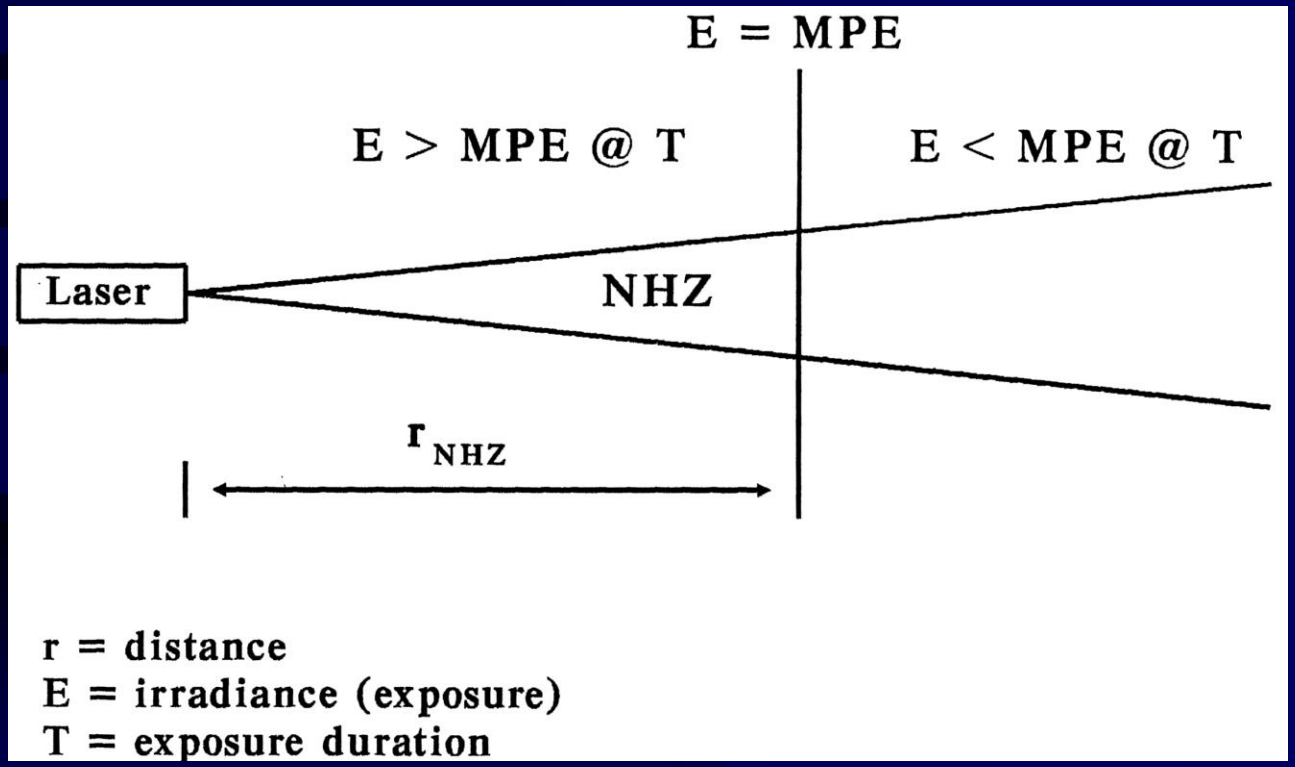
See equation for calculating diameter of beam at distance r from the laser.

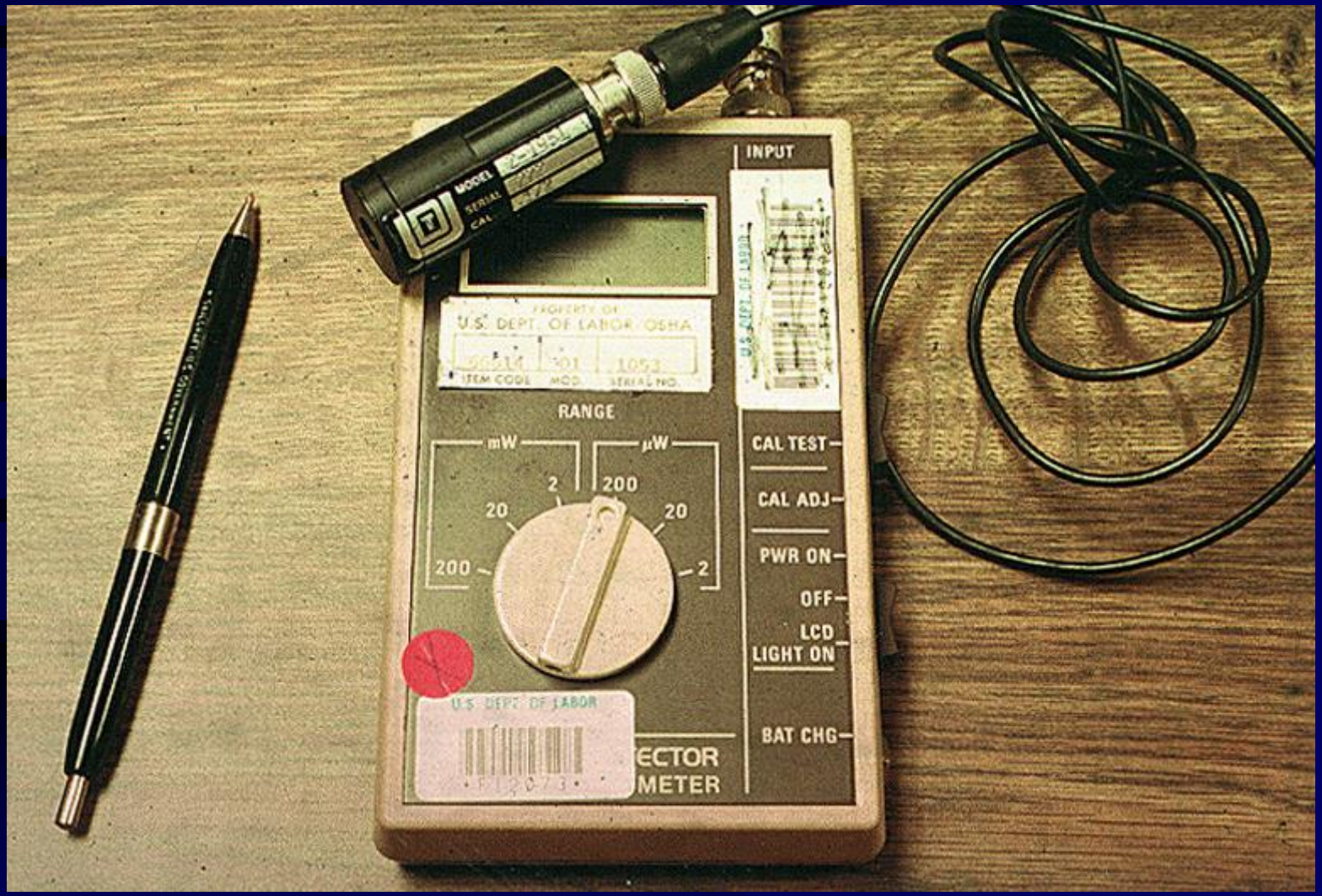
Specular (Mirror) Reflection

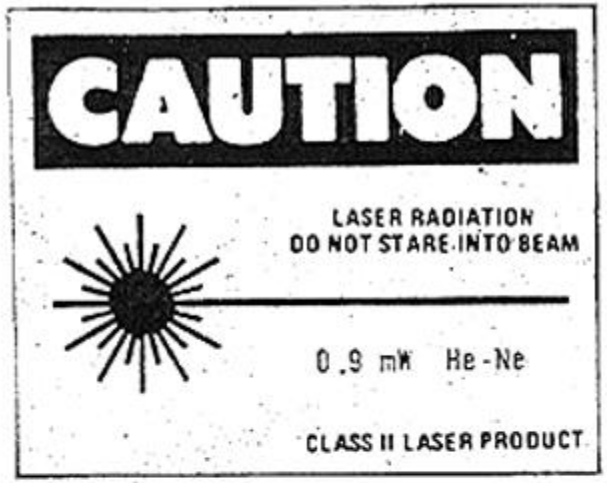


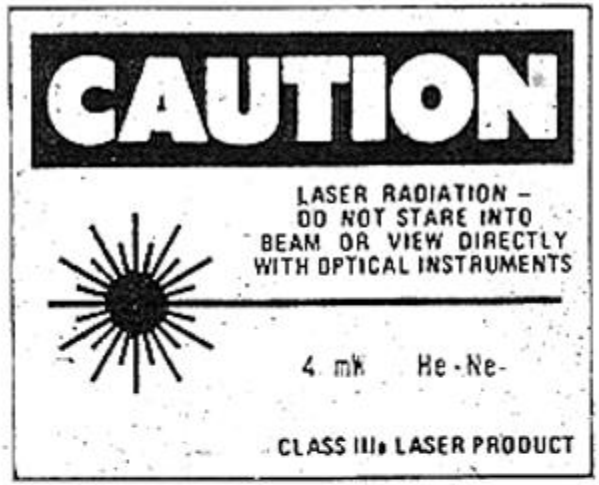
Specular reflection (left illustration) retains the columnar beam, and therefore, intra-beam exposure.

Nominal Hazard Zone




INPUT
PROPERTY OF
U.S. DEPT. OF LABOR OSHA
ITEM CODE
MOD.
SERIAL NO.
RANGE
mW
µW
2
20
200
200
20
2
CAL TEST
CAL ADJ
PWR ON
OFF
LCD
LIGHT ON
BAT CHG
U.S. DEPT. OF LABOR
ECTOR
METER


CAUTION
LASER RADIATION
DO NOT STARE INTO BEAM
0.9 mW He-Ne
CLASS II LASER PRODUCT

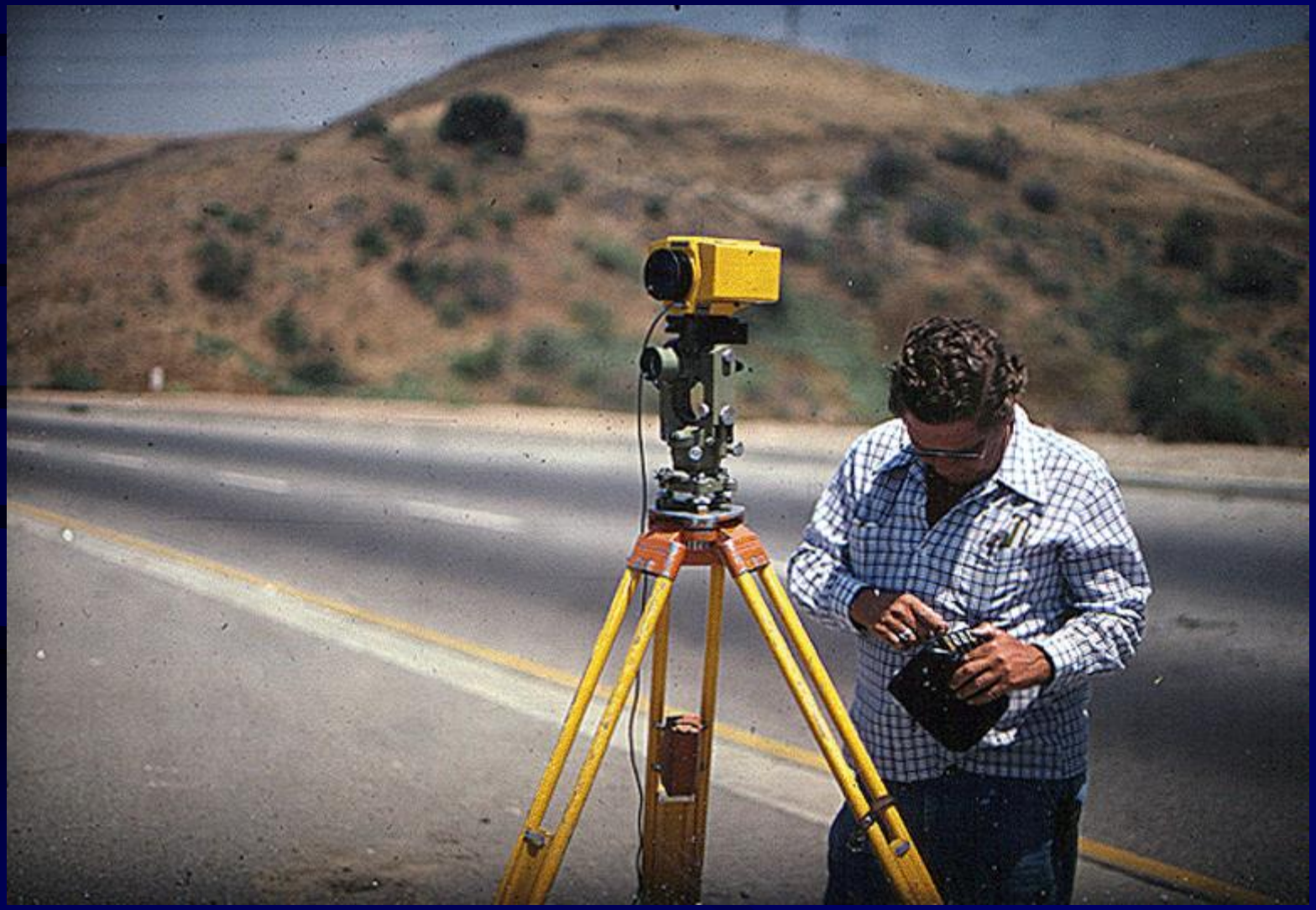

CAUTION
LASER RADIATION –
DO NOT STARE INTO
BEAM OR VIEW DIRECTLY
WITH OPTICAL INSTRUMENTS
4 mW He-Ne-
CLASS IIIb LASER PRODUCT

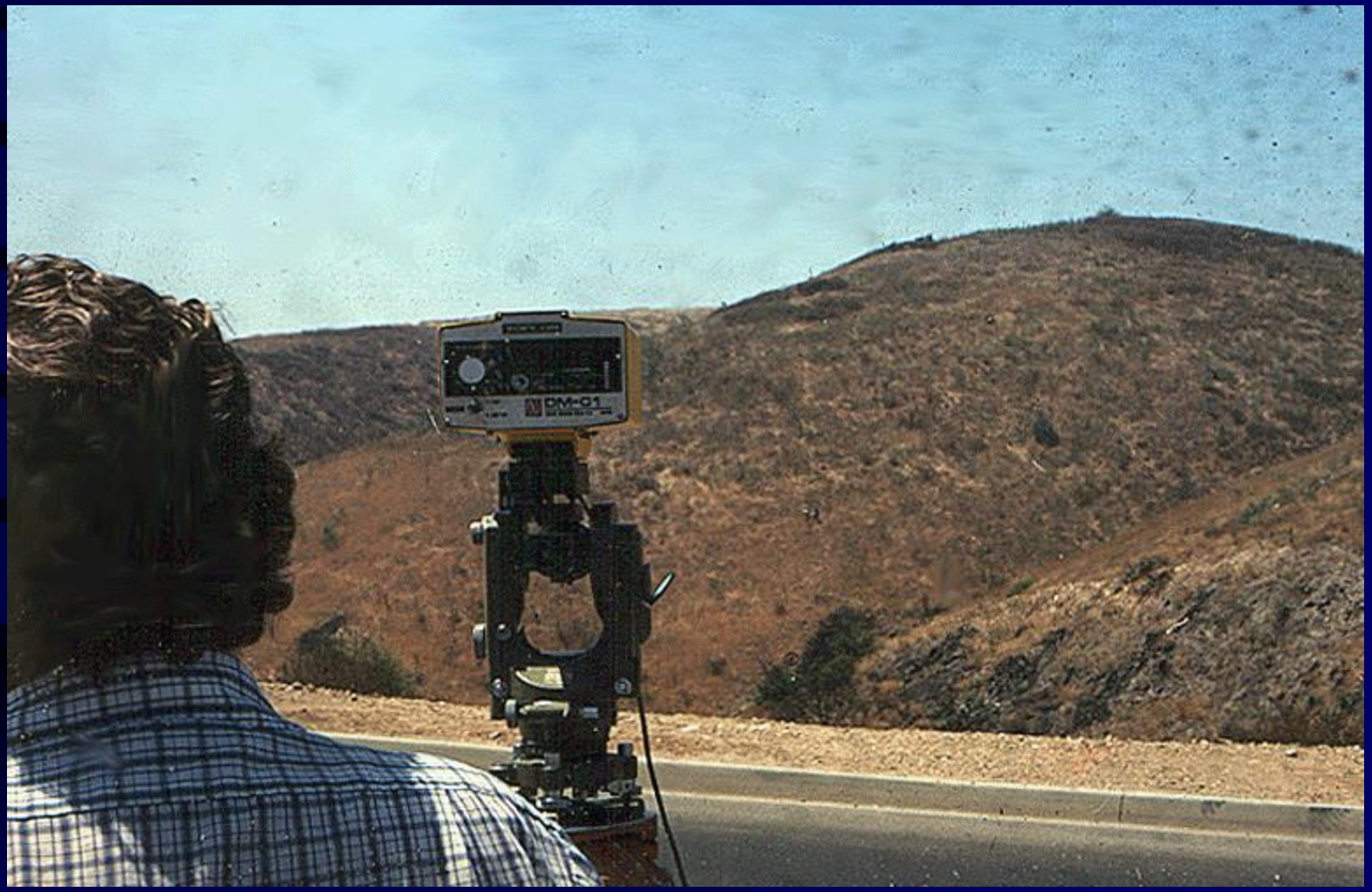

DANGER
LASER RADIATION –
AVOID DIRECT EXPOSURE
TO BEAM
50 mJ 1064 nm
20 ns Pulse
CLASS IIIb LASER PRODUCT


DANGER
LASER RADIATION –
AVOID EYE OR SKIN EXPOSURE
TO DIRECT OR SCATTERED
RADIATION
50 W CO_2
CLASS IV LASER PRODUCT

Laser Hazard Classifications

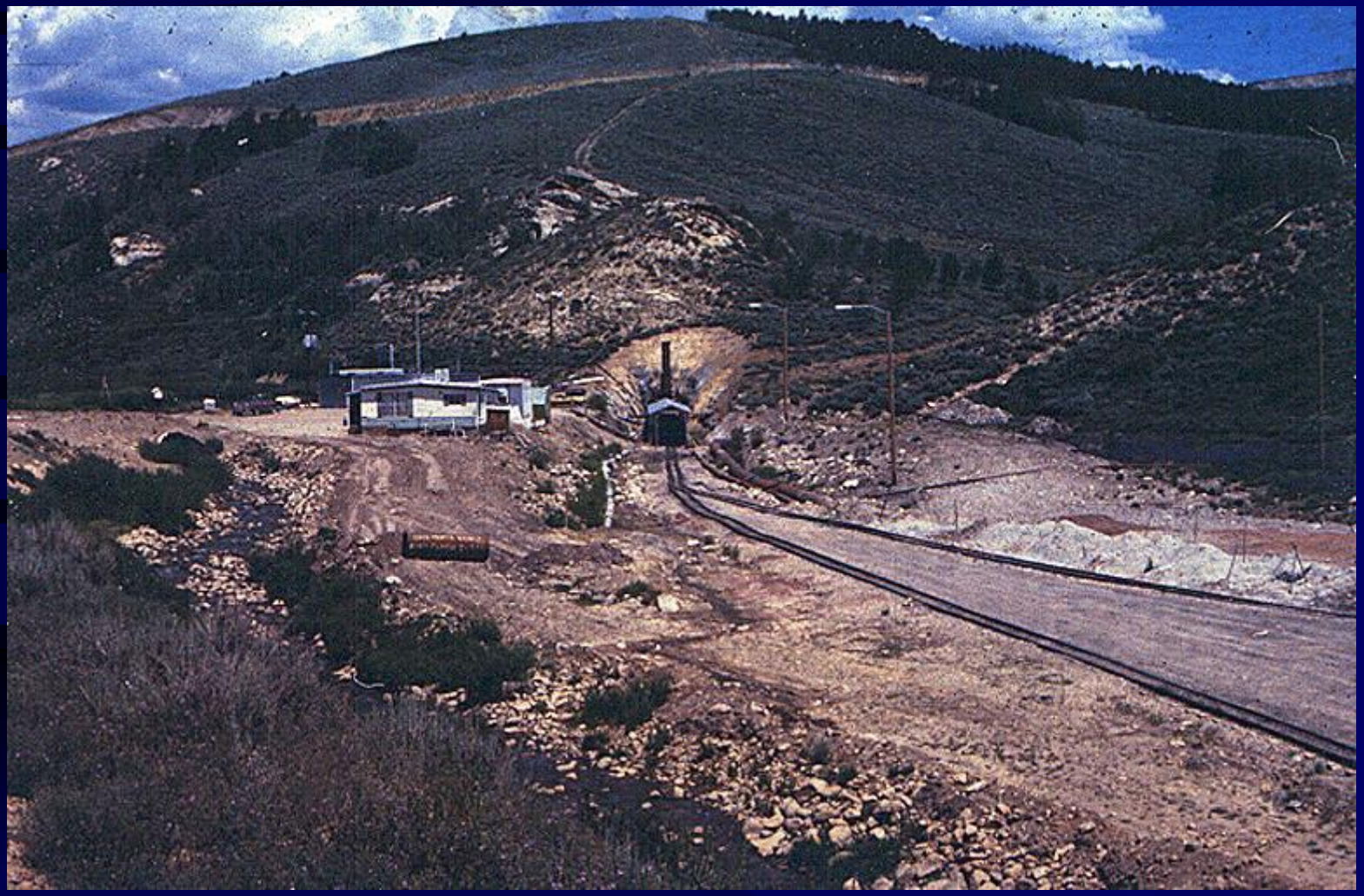
- Class 1 - “safe” if not disassembled
  - CD-ROM players/drives
- Class 2/2a - eye hazard if you stare into beam
  - supermarket scanners

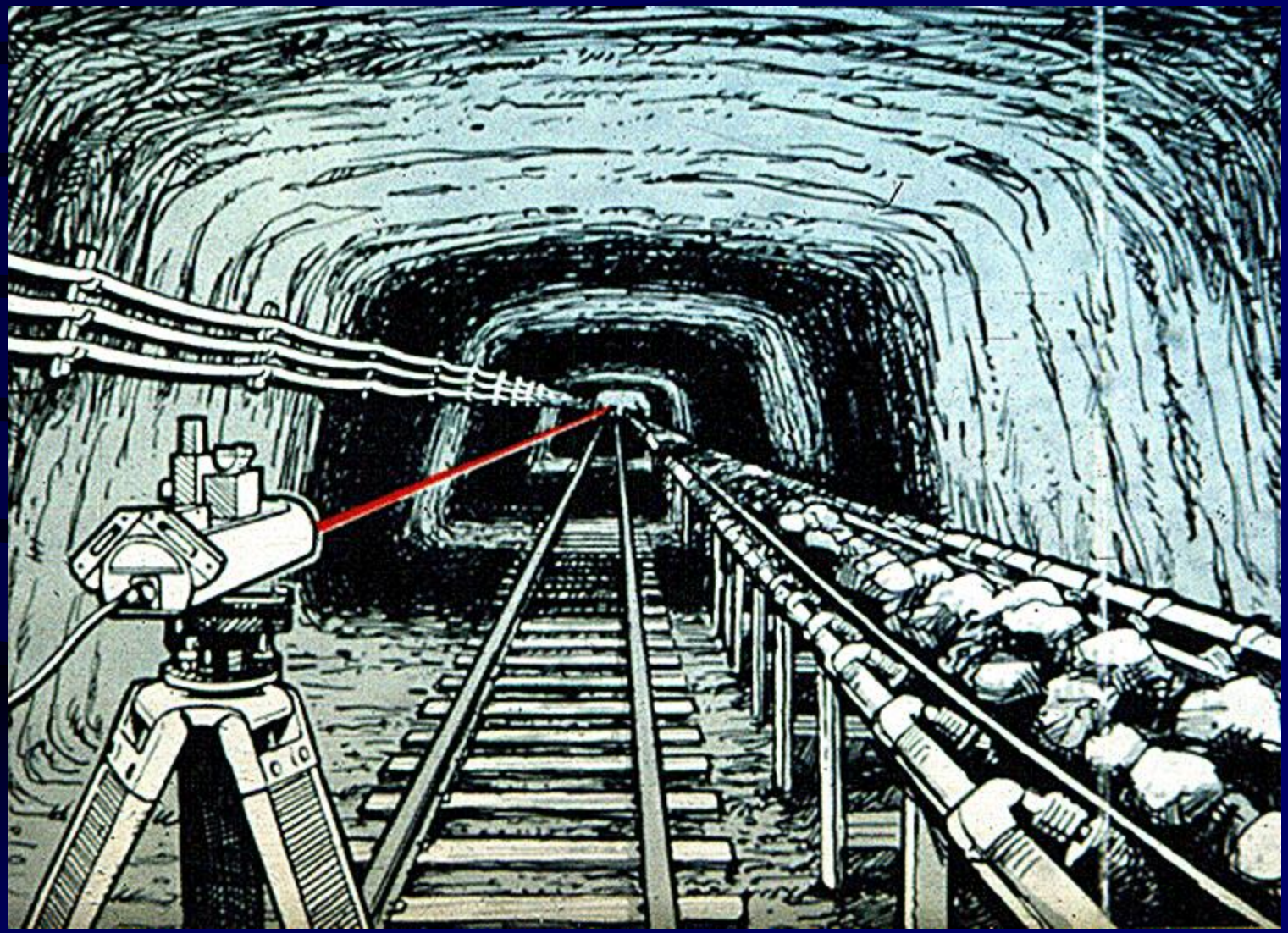



DM-01

Laser Hazard Classifications

- Class 3a - eye hazard if collected or focused into eye
  - laser pointers
- Class 3b - eye hazard if direct or reflected beam is viewed
  - research
- Class 4 - eye hazard if direct, reflected or diffusely-reflected beam is viewed; possible skin and fire hazard
  - research, manufacturing





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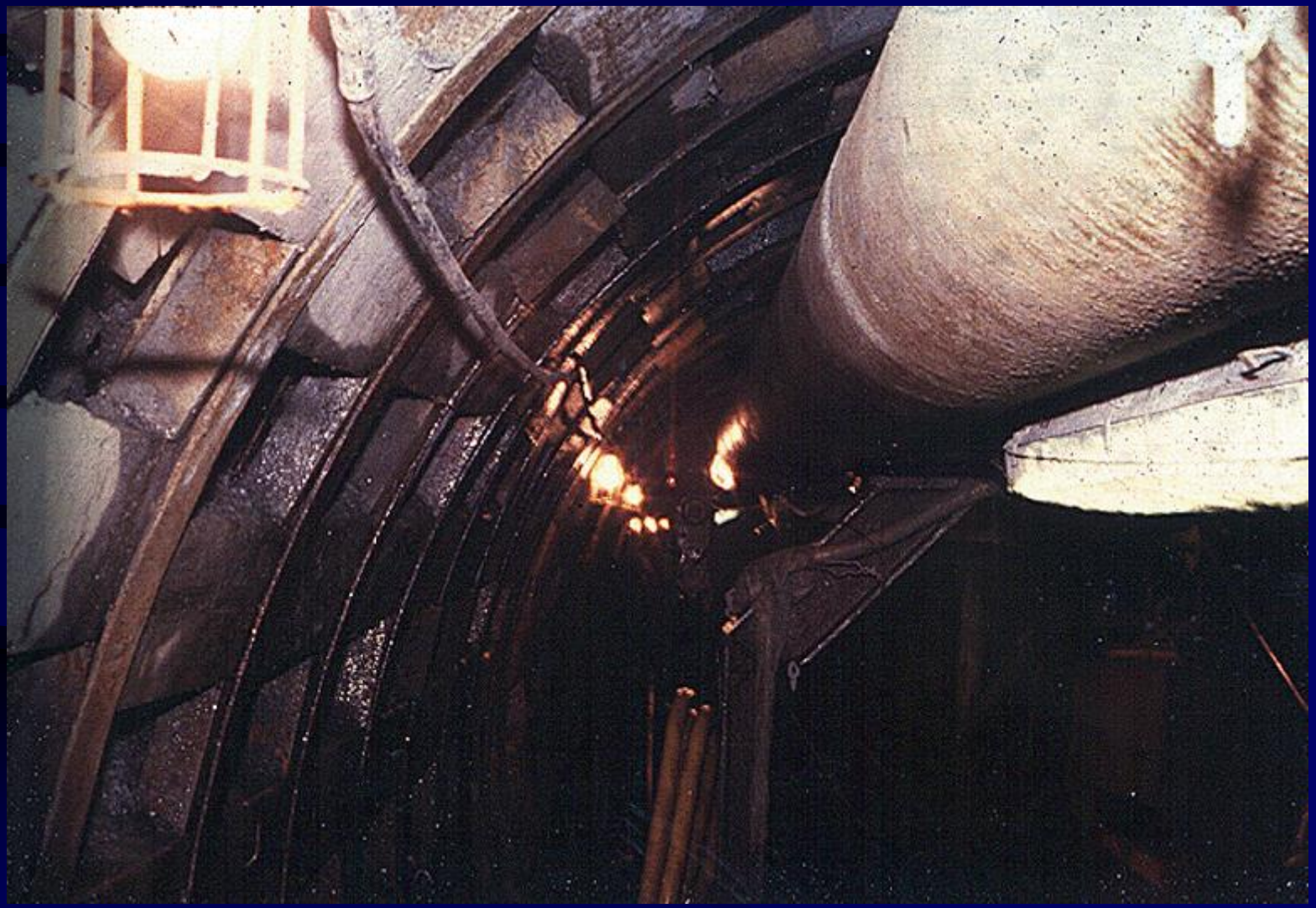

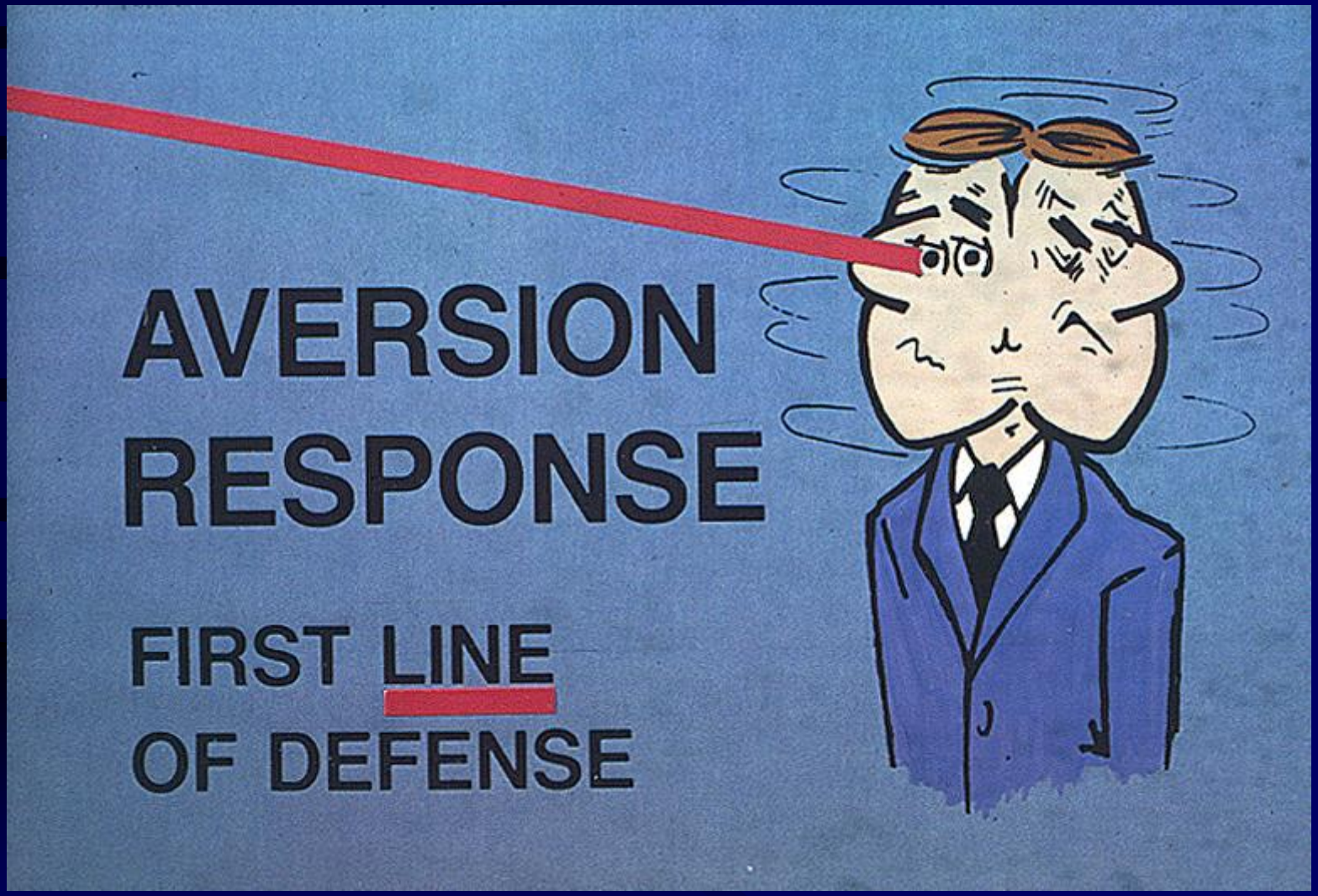

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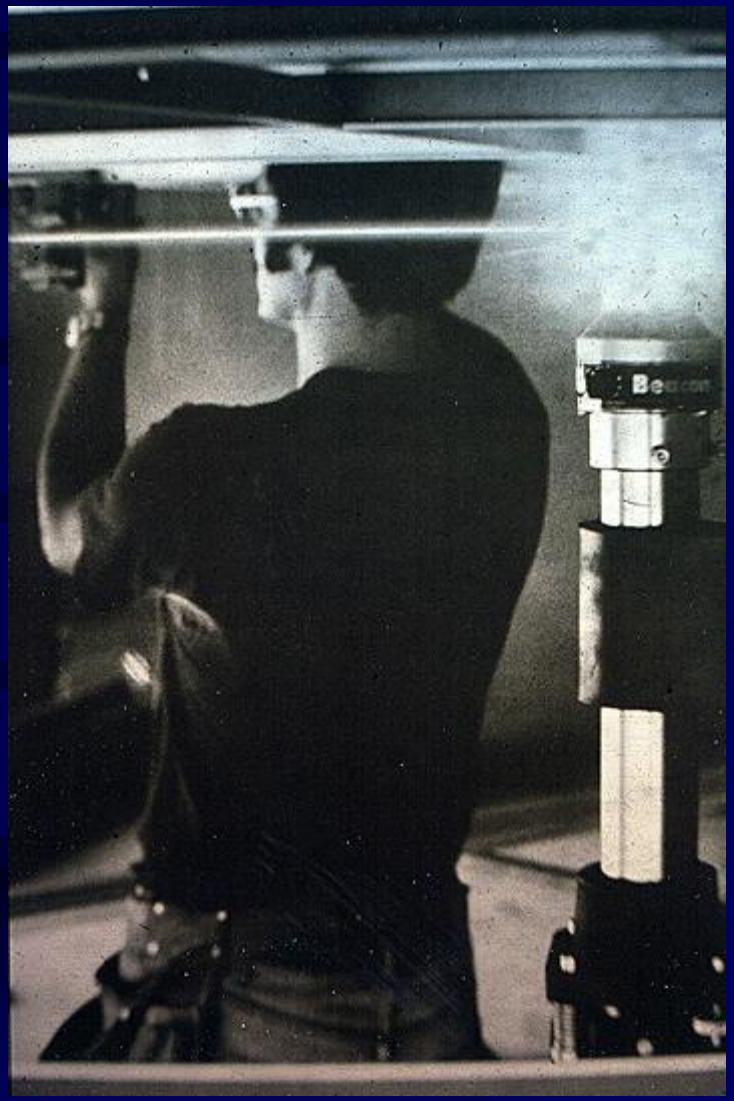
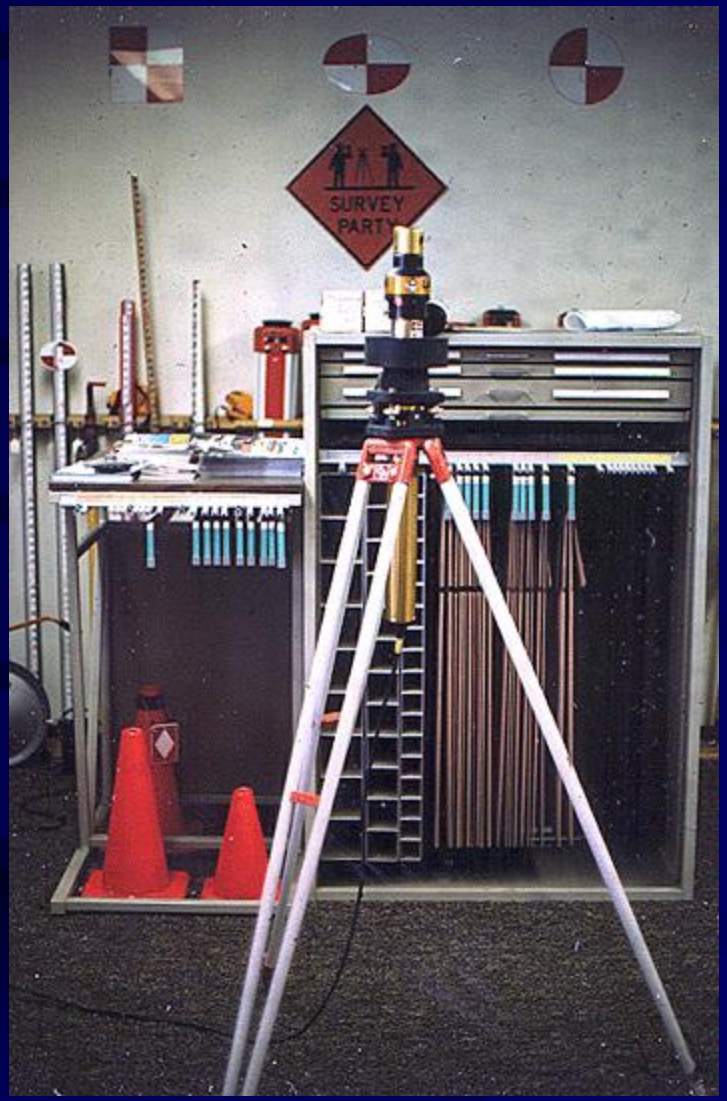
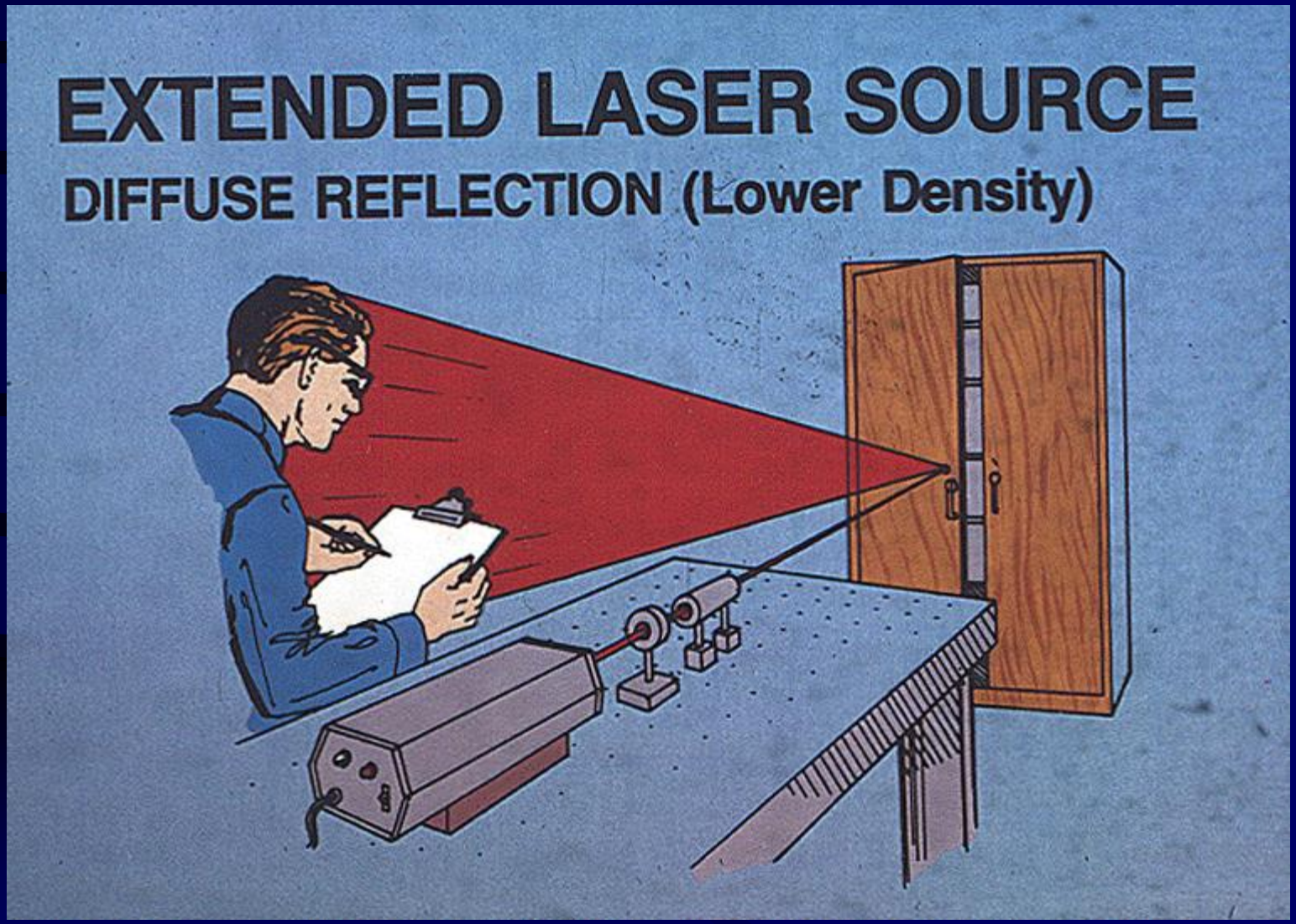



SURVEY
PARTY



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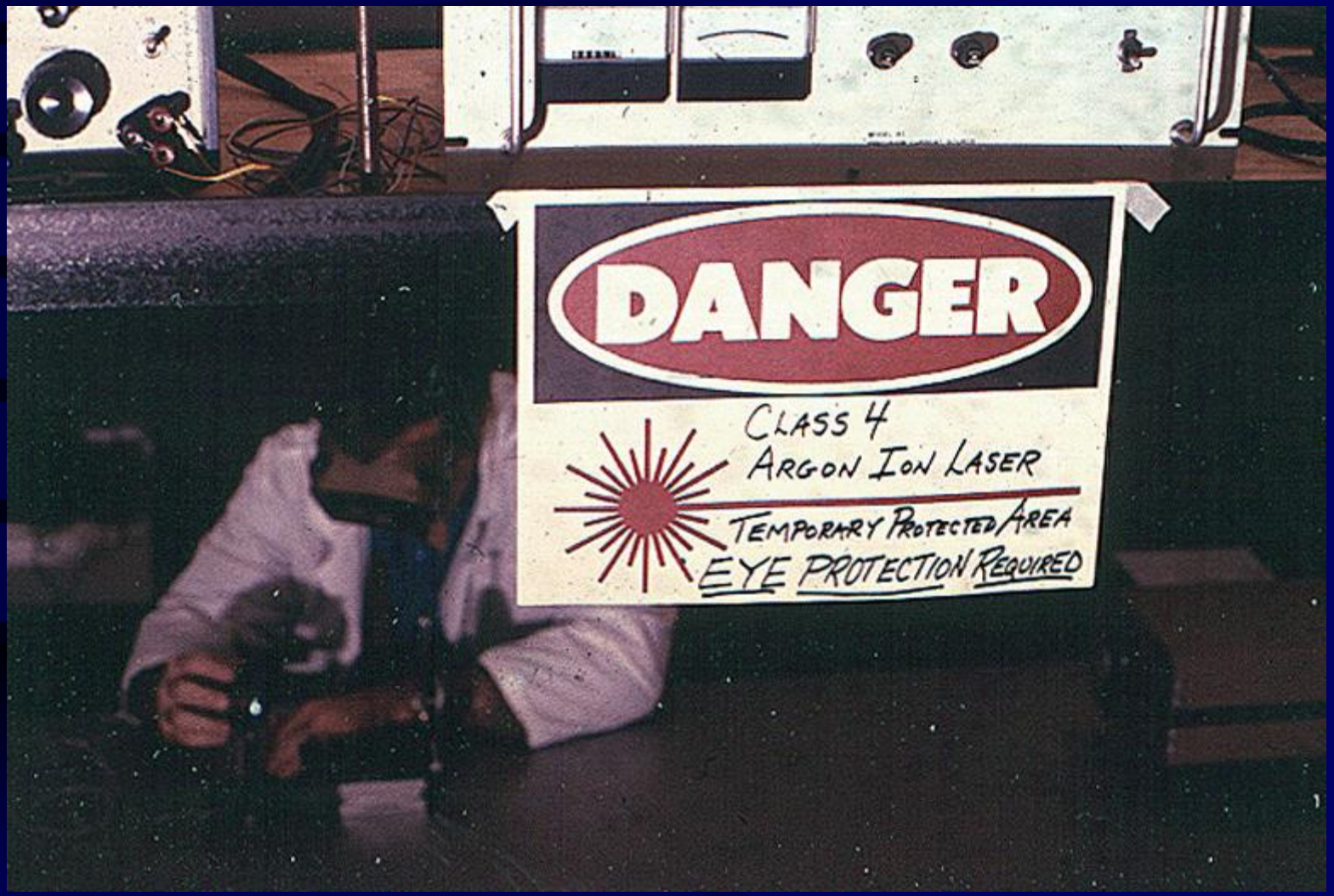
DANGER
CLASS 4
ARGON ION LASER
TEMPORARY PROTECTED AREA
EYE PROTECTION REQUIRED

PPE Control Measures

- *Appropriate* eyewear
- Gloves
- Special clothing

eyewear must be for the appropriate laser wavelength, attenuate the beam to safe levels, yet be comfortable enough to wear

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TABLE 28-7

Minimum Optical Densities Required of Protective Eyewear

($OD_{min} = \log_{10} H_o/MPE$ or $\log_{10} E_o/MPE$)

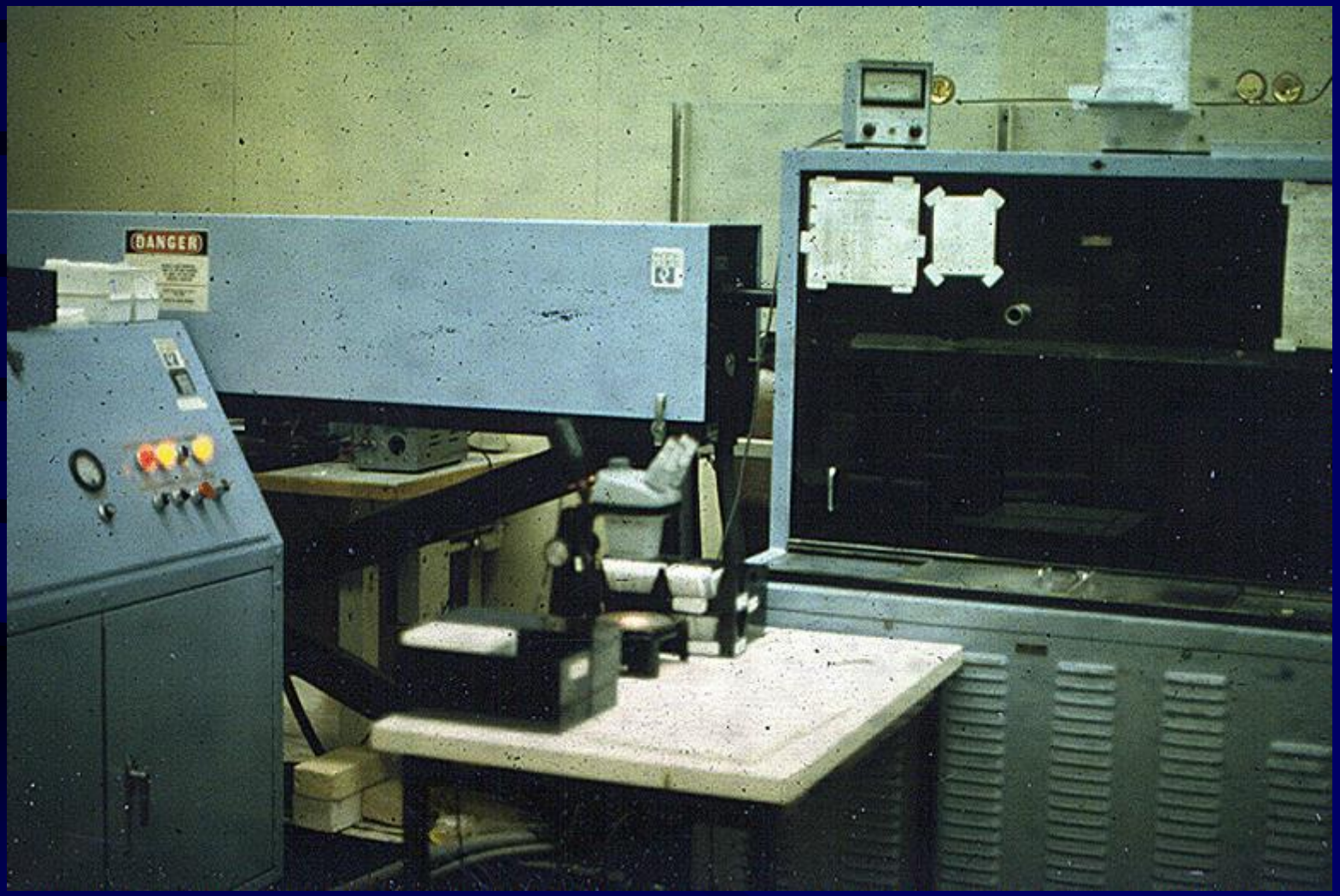
E_o/MPE or H_o/MPE	OD_{min}
$1 = 10^0$	0
$10 = 10^1$	1
$100 = 10^2$	2
$1000 = 10^3$	3
$10000 = 10^4$	4
$100000 = 10^5$	5
$1000000 = 10^6$	6

Where H_o is equal to the emergent beam radiant exposure in Joules per square centimeter and E_o is equal to the emergent beam irradiance in Watts per square centimeter.

Engineering Control Measures

- Beam housings
- Shutters
- Attenuators
- Remote firing controls
- Interlocks

curtains between laser systems


DANGER

Administrative Control Measures

- Warning signs/labels
- SOPs
- Training

Administrative Safety Practices

- Supervisors are responsible for training users
- Standard Operating Procedures
- Authorized personnel only in vicinity of laser
- Designate NHZ for Class 3b and 4 lasers
- Address non-beam hazards

Common Causes of Accidents

- Altering beam path (e.g., adding optical components without regard to beam path)
- Inserting reflective objects into beam path
- Bypassing interlocks (particularly during alignment)
- Accidentally turning on power supply
- Accidental firing of laser

General Safety Practices While Working

- Wear appropriate protective eyewear
- Use minimum power/energy required for project
- Reduce laser output with shutters/attenuators, if possible
- Terminate laser beam with beam trap
- Use diffuse reflective screens, remote viewing systems, etc., during alignments, if possible
- Remove unnecessary objects from vicinity of laser
- Keep beam path away from eye level (sitting or standing)

Don't put your body parts (particularly your eyes) in the beam!

Non-beam Hazards - Optical

- UV from laser welding
- UV from discharge tubes and pumping lamps
- Visible and IR-A from pumping systems

Use shielding to prevent injury

Non-beam Hazards - Chemical

- Organic dyes are major source of chemical hazard
- Mutagenic, carcinogenic, toxic and/or highly reactive chemicals
- Gases from laser or interaction of laser with target

Use standard laboratory safety techniques to prevent injury (PPE, proper chemical storage, fume hood)

Non-beam Hazards - Electrical

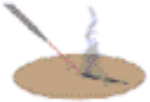
- Most common non-beam hazard
- Watch out for high voltage from power supplies, capacitor banks

Use standard electrical safety techniques to prevent injury

Non-beam Hazards - Fire

- Electrical circuits
- Improper beam enclosures
- Ignition of gases/fumes
- Flammable dyes

Use flame-resistant beam enclosures and check electrical circuits for safety to prevent injury



Safety and Health Topics:

Laser Hazards

October 7, 2002

Safety and Health Topics

Laser Hazards
- Recognition
- Evaluation
- Control
- Compliance
- Training
- Other
- Credits

Related Technical Links

- Construction: Laser Hazards
- Laser/Electrosurgery Plume

Recognition

- Laser Hazards. OSHA Technical Manual (TED 1-0.15A), Section III - Chapter 6 (1999, January 20), 51 pages. This chapter contains information that will assist in the recognition and evaluation of laser hazards.
- Laser Systems. OSHA Hazard Information Bulletin (1988, April 29), 1 page. Alerts OSHA field compliance and consultation personnel to the importance of careful evaluation of laser systems, the environment in which the laser is used, and the possible exposure of workers to laser radiation.
- Guidelines for Laser Safety and Hazard Assessment. OSHA Instruction PUB 8-1.7 (1991, August 5), 70 pages.
- Hazard of Laser Surgery Smoke. OSHA Hazard Information Bulletin (1988, April 11), 1 page. Links potential airborne biological hazards with the use of lasers during surgery.
- Hospital Investigations: Health Hazards. OSHA Technical Manual (TED 1-0.15A), Section VI - Chapter 1 (1999, January 20), 22 pages. Describes lasers as a potential hazard in the hospital environment and identifies areas to investigate.
- Physical Agents. OSHA Technical Manual (TED 1-0.15A), Section VI - Chapter 1, Appendix VI:1-3 (1999, January 20). Identifies the acute effects of laser exposure. It also states that chronic effects are unknown.
- Laser Safety Information. University of Illinois at Urbana-Champaign. Manual to aid in the recognition of laser hazards.
- Laser Hazards and Hazards Evaluation. Oklahoma State University Laboratory Safety Manual, Chapter 6, 4 pages.
- Laser Accident Database Menu. Rockwell Laser Industries. Contains laser accident information dating from 1964 to 1996.

Evaluation

- FDA/CDRH Federal Product Performance Standard Evaluation Outline. OSHA Technical Manual (TED 1-0.15A), Section III - Chapter 6, Appendix III:6-2 (1999, January 20).