National Institutes of Health
Office of Management

NIH LASER SAFETY TRAINING

Presented by the NIH Laser Safety Team at the Division of Occupational Health and Safety, DOHS

Email: lasersafety@mail.nih.gov
Phone: 301-496-2960

Office of Research Services
National Institutes of Health
U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES

Outline

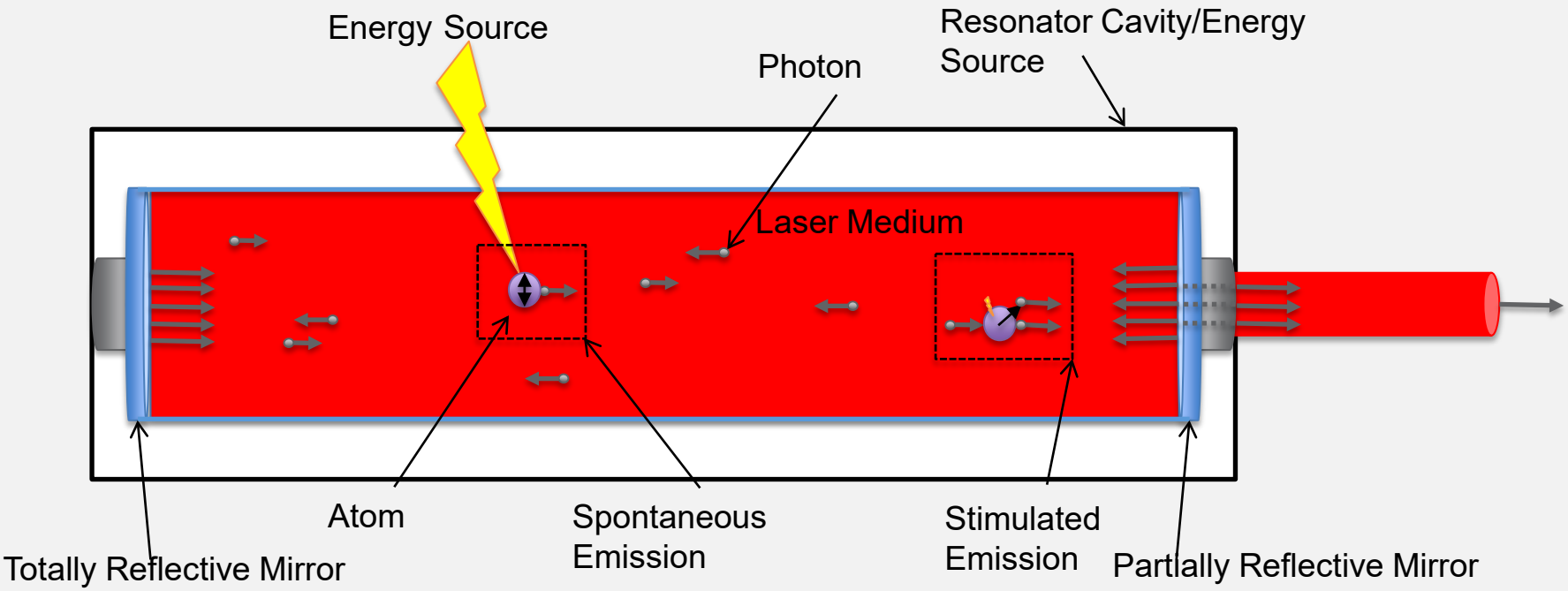
- What is a Laser? Lasers Mechanism.
- Lasers Types and its applications.
- Lasers Wavelength and Absorption.
- Biological Effects of Lasers.
- Lasers Classification and Hazards.
- Best Work Practices and Personal Protective Equipment.
- The NIH Laser Safety Program Scope and Requirements.
- Embedded Laser Equipment and Requirements.
- Responsibilities.
- Emergency Procedures.
- Link to the Quiz.

Introduction

- The applications of lasers in biomedical research and in clinical treatments have grown.
- At NIH the spectrum has been on display: used from optical imaging to laser eye treatment.
- Novel laser technologies are evolving as personnel working with lasers increase.
- In that sense, safe use of lasers is necessary.

What is a Laser?

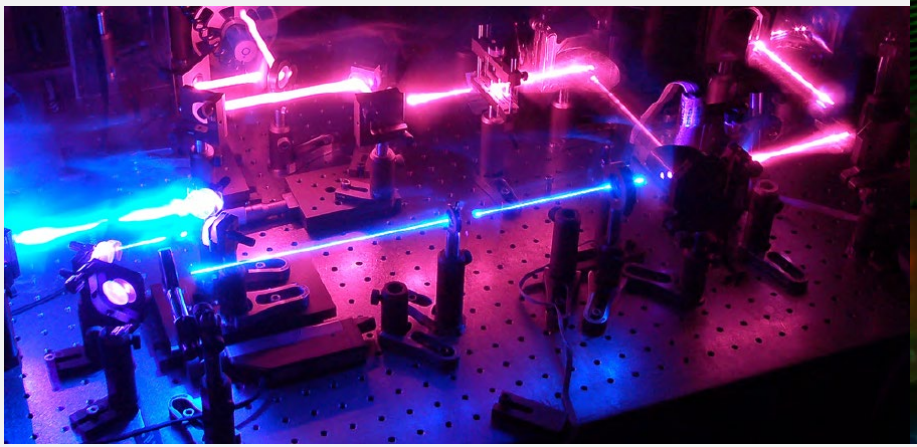
- **Light Amplification by the Stimulated Emission of Radiation**

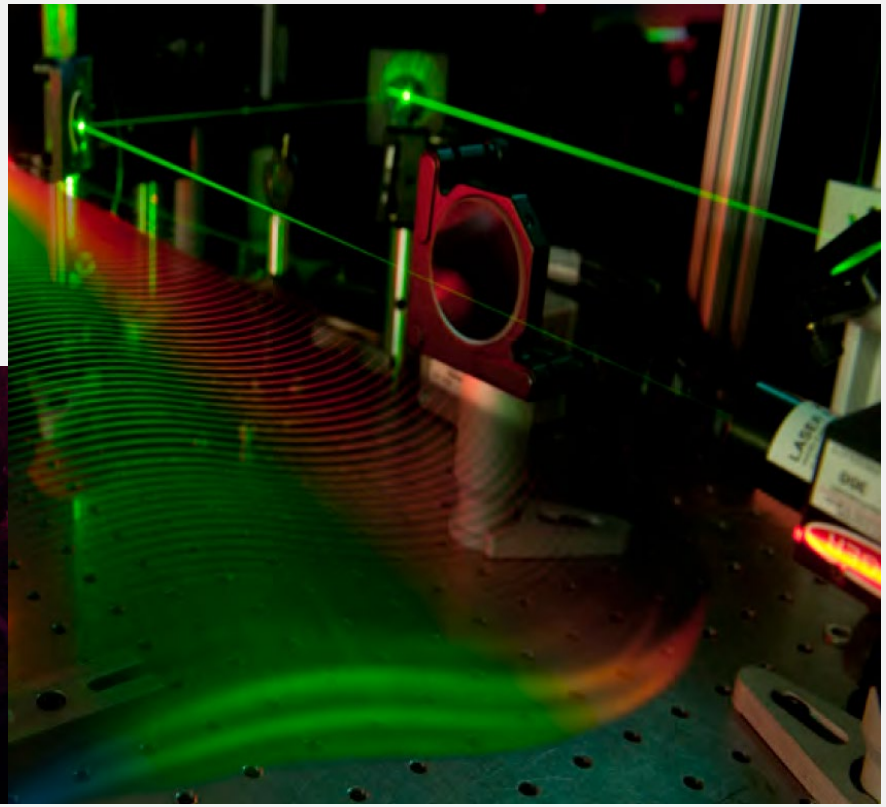


What is a Laser?

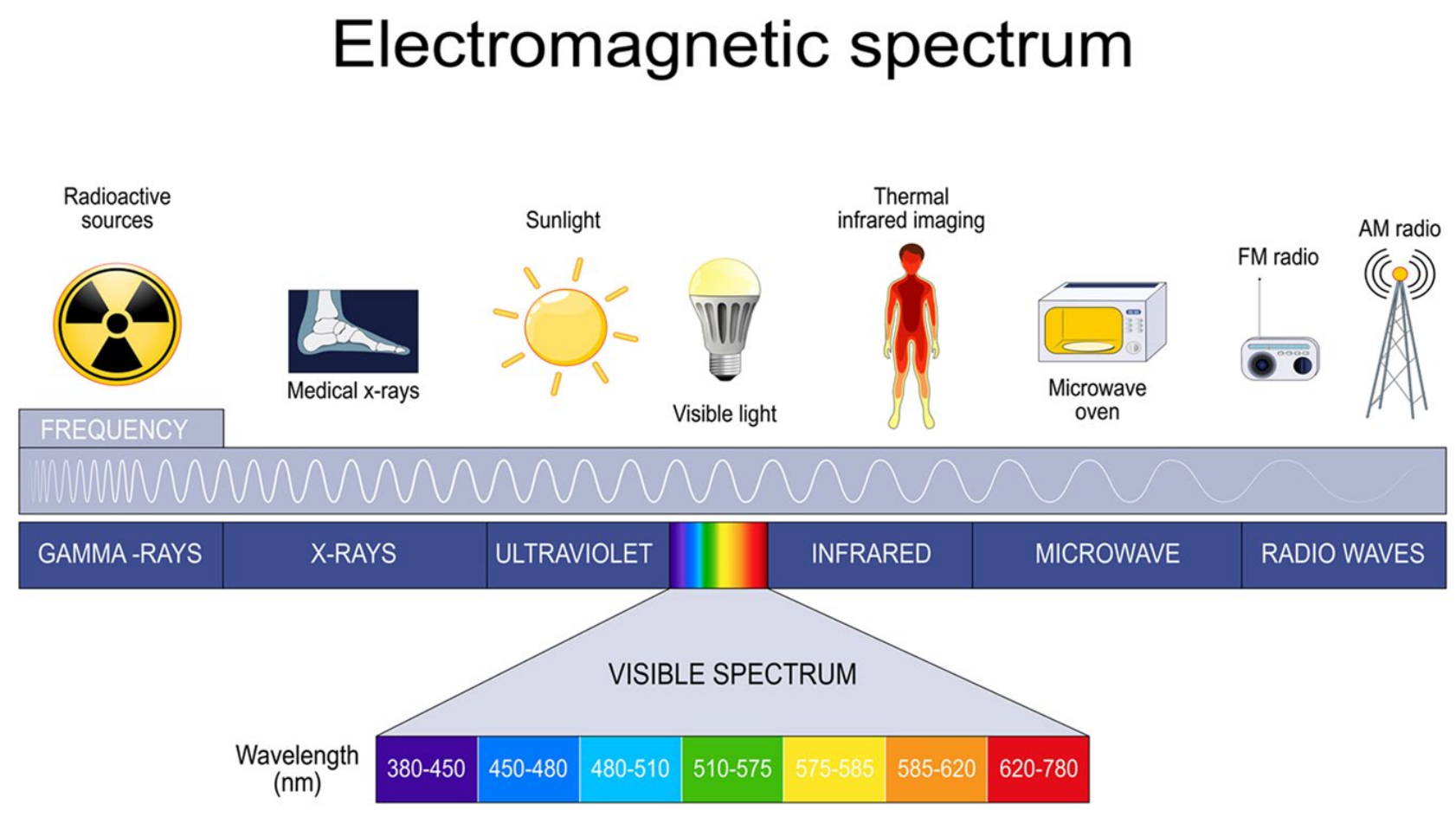
Laser Light features

- Monochromatic (single wavelength)
- Coherent (waves in phase)
- Collimated (Directional)
- Intense (high energy in a small area)

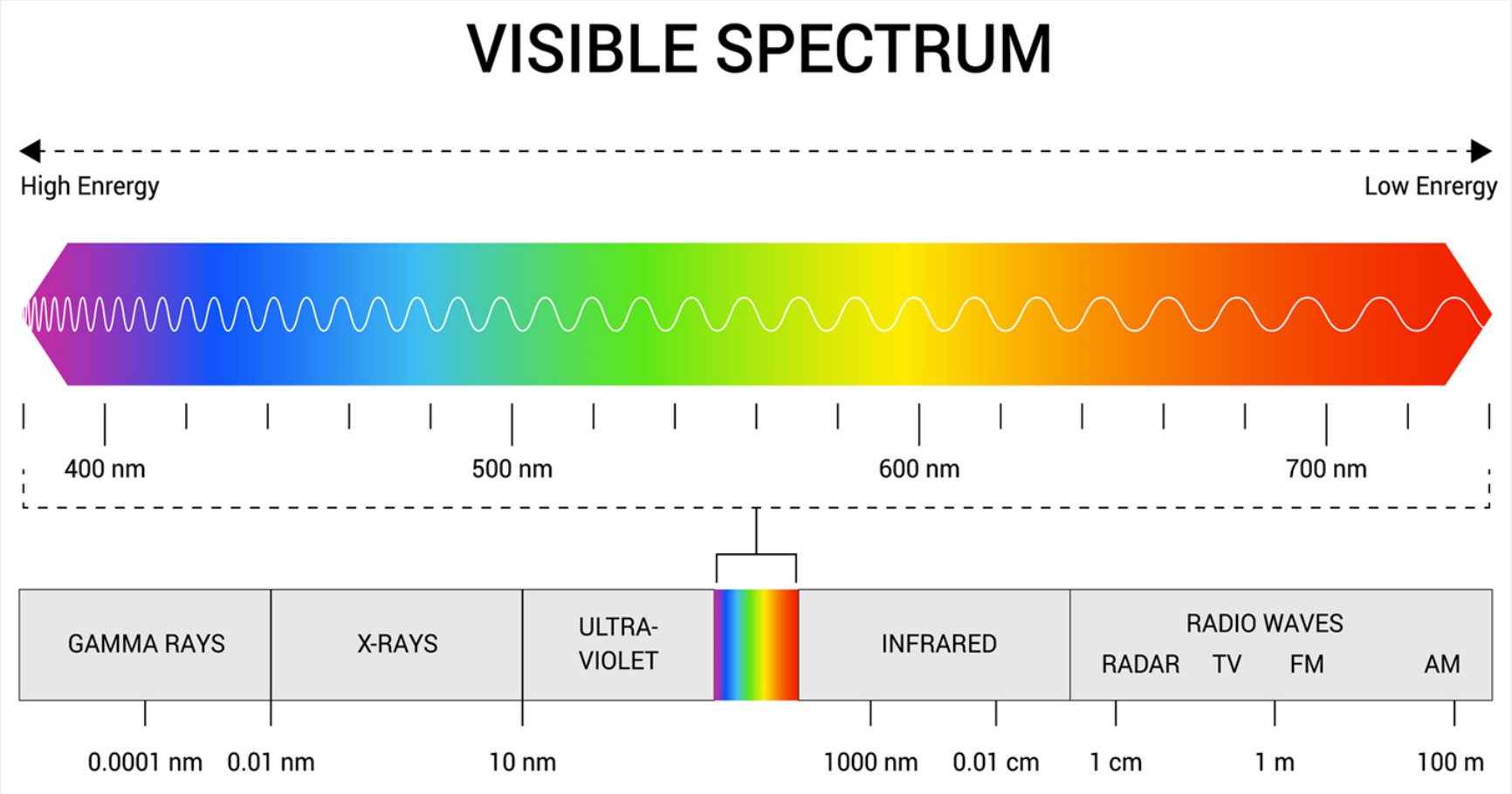




Lasers in the Energy Spectrum



Laser Visible Spectrum



Types of Lasers

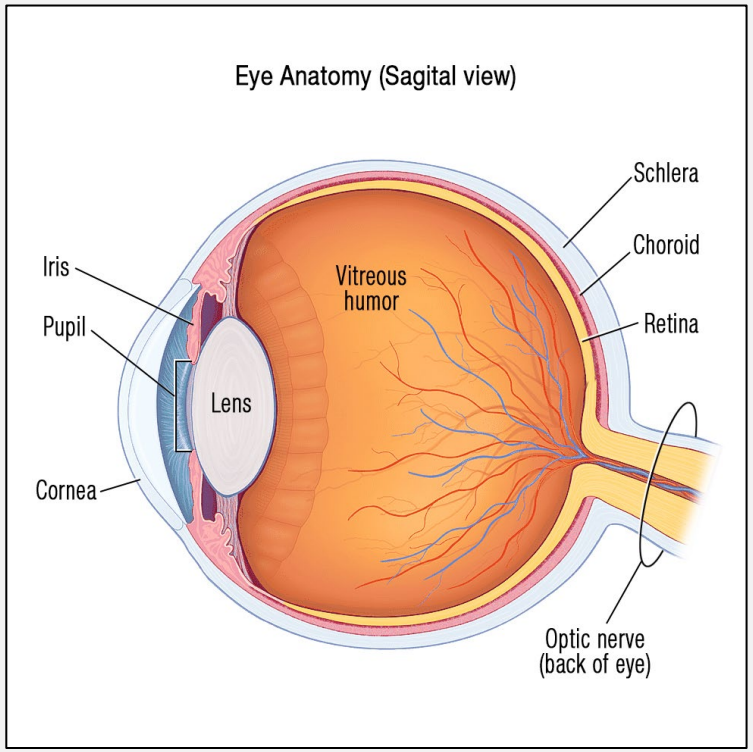
- Gas Lasers: CO2, helium-neon and krypton.
- Solid-State Lasers (crystals or glasses):YAG laser.
- Fiber Lasers: Optical fiber.
- Liquid Lasers (Dye Lasers): Tunable lasers.
- Semiconductor Lasers (Laser Diodes): most used at NIH

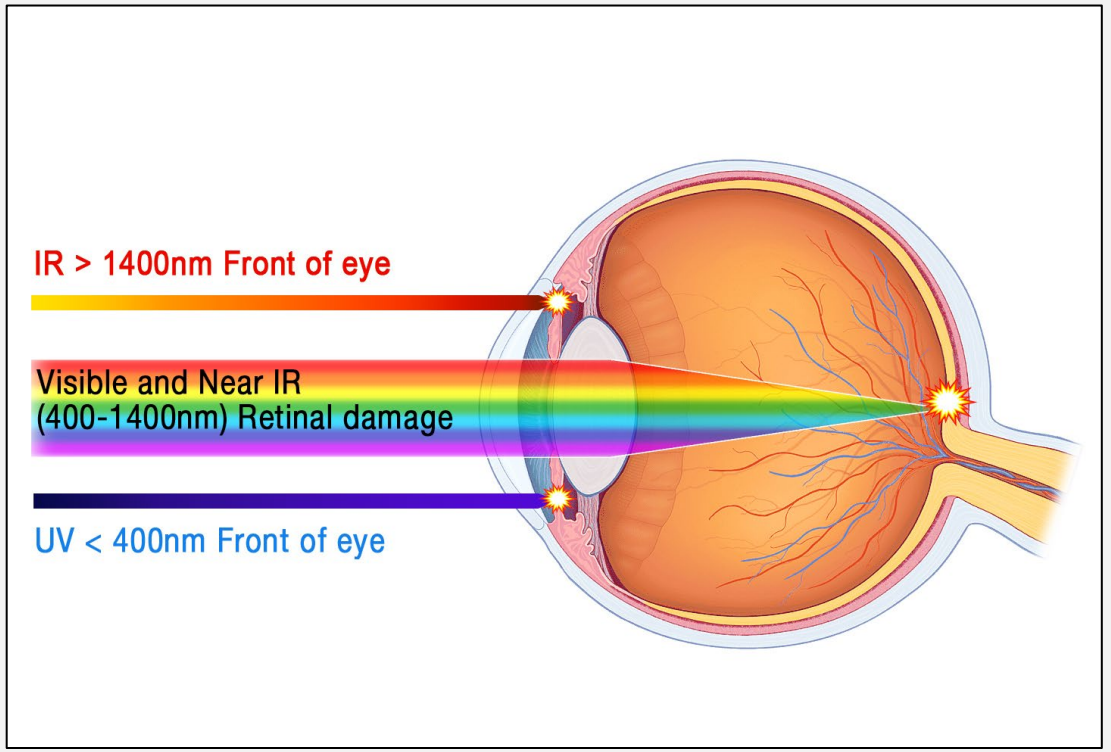
-Diode-pumped: use electrical energy sources to pump other lasers.

Laser Applications

- **Commercial:** Laser printing, optical drives, thermometers, barcode scanning (Diode/Gas).
- **Defense**: Blinding weapon, target marking, tracking, missile defense, weapons guiding (Diode).
- **Industrial**: Cutting, welding, marking (Gas).
- **Medical/healthcare**: Surgery, dentistry, eye treatment, skin treatment hair removal (Dye/Gas).
- **Research:** Spectroscopy, microscopy, scattering, microdissection (Gas/Diode).

Laser Wavelengths and Optical Absorption





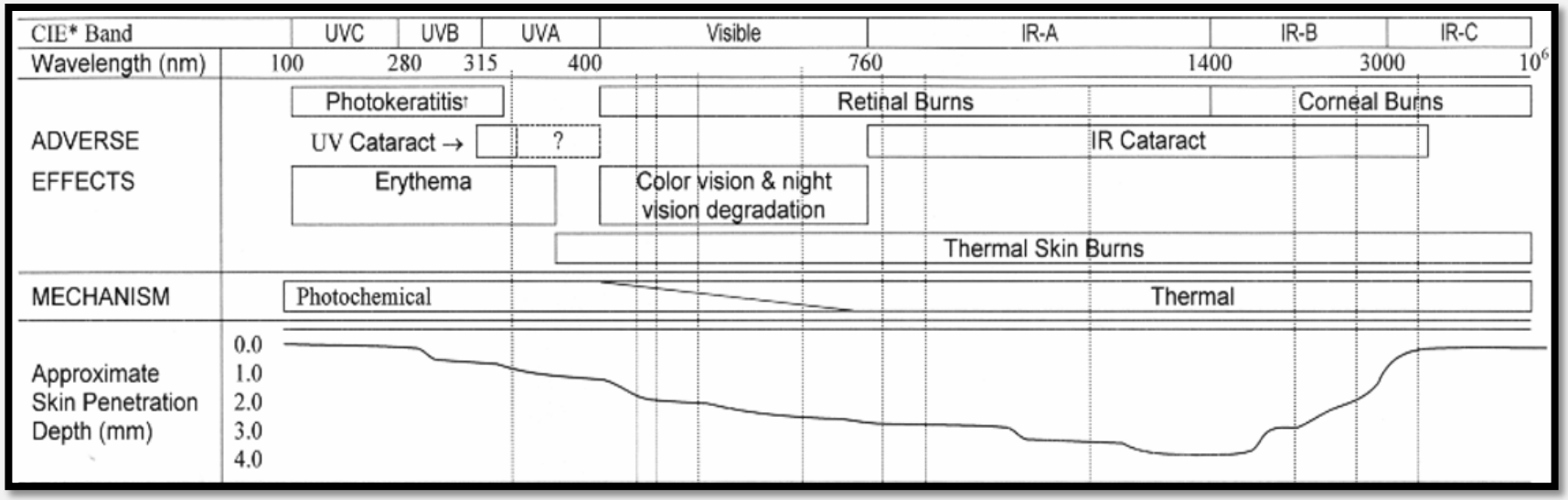
Biological Effects of Lasers

- **Ultraviolet [UV]:** photochemical mechanism of interaction. Overexposure can cause erythema (sunburn), cataracts & age-related macular degeneration (blindness), photo keratitis (corneal burn) & skin cancer.
- **Visible:** photochemical & thermal mechanism. Overexposures can cause retinal & skin burns, cataracts, and degradation of color & night vision.
- **Infrared [IR]:** thermal mechanism of interaction. Overexposure can cause skin burns, cataracts, and (depending on λ) corneal or retinal burns.

Biological Effects of Lasers

Factors affecting biological effects:

- Frequency/Wavelength
- Power
- Beam Diameter & Divergence
- Exposure Duration



Laser Output and Exposure

Output [at laser]:

- Radiant Energy (joule, J) - ability to do work.
- Radiant Power (Watt, W) - rate at which work is done.

Exposure [at target]:

- Radiant Exposure (J/cm²) – Energy per unit area; like "dose"; applies to photochemical effects & pulsed lasers.
- Irradiance (W/cm²) – Power per unit area; like "dose rate"; applies to thermal effects.

Laser Exposure Components

- **Maximum Permissible Exposure (MPE):** The level of radiation to which an unprotected person may be exposed without adverse biological changes in the eye or skin.
  - The MPE varies by wavelength and duration of exposure referenced in tables of the ANSI Z136.1 standard.
  - MPE is considered laser safety speed limit and can be determined based on continuous wave or repetitive pulse laser.

- **Nominal Hazard Zone (NHZ):** The space within which the level of the direct, reflected, or scattered radiation may exceed the applicable MPE. Exposure levels beyond the boundary of the NHZ are below the appropriate MPE.

Laser Product Hazard Classification

Class (FDA)	Class (IEC)	Laser Product Hazard
I	1, 1M	Considered non-hazardous. Hazard increases if viewed with optical aids, including magnifiers, binoculars, or telescopes.
IIa, II	2, 2M	Hazard increases when viewed directly for long periods of time. Hazard increases if viewed with optical aids.
IIIa	3R	Depending on power and beam area, can be momentarily hazardous when directly viewed or when staring directly at the beam with an unaided eye. Risk of injury increases when viewed with optical aids.
IIIb	3B	Immediate skin hazard from direct beam and immediate eye hazard when viewed directly.
IV	4	Immediate skin hazard and eye hazard from exposure to either the direct or reflected beam; may also present a fire hazard.

The NIH Laser Safety Program performs surveillance for Class 3B and 4 laser products.

Table recreated from: https://www.fda.gov/radiation-emittingproducts/radiationemittingproductsandprocedures/homebusinessandentertainment/laserproductsandinstruments/default.htm

Laser Hazard Classification

- The NIH Laser Safety Program (LSP) has been developed to align with the American National Standards Institute (ANSI) Z136.1.
- The ANSI Z136.1 classifies each type of laser by its potential for biological harm. These classifications are Class 1, Class 1M, Class 2, Class 2M, Class 3R, Class 3B, and Class 4.
- Class 1 lasers being exempt from any kind of control due to their lack of hazard and Class 4 lasers requiring strict controls to reduce the risk of exposure to the eyes or skin. The specific controls for each classification are thoroughly described in the standard.

ANSI Z136.1 Laser Class Requirements

Class	Control Measures	Training	LSO	Engineering Controls
1	Not Required	Not Required	Not Required	Not Required
1M	Required	Application Dependent	Application Dependent	Application Dependent
2	Not Required	Not Required	Not Required	Not Required
2M	Required	Application Dependent	Application Dependent	Application Dependent
3R	Not Required	Not Required	Not Required	Not Required
3B	Required	Required	Required	Required
4	Required	Required	Required	Required

Lasers Hazards

Eye Injury

- Acute and chronic exposure: Corneal, optical nerve, retinal injury, lens damage.
- Severely damaged vision could cause blindness.

Protection

- Avoid direct viewing of the laser and its reflection.
- Maximum enclosure of the laser can reduce the risk of eye exposure without eye protection.
- Appropriate eye protection can protect against various forms of laser radiation which could affect eye tissues.

Lasers Hazards

Skin Injury (high power lasers/typically Class 4)

- Acute: Burns.
- Chronic: skin cancer, rapid aging of the skin are possible from exposure to laser radiation, increase in pigmentation, photosensitivity.

Protection

- Avoid skin contact to lasers beam.
- Wear long sleeves and gloves if necessary (e.g: during alignment).

Laser Hazards

Non- Beam Hazards: Lasers induced reactions can release hazardous particulate, gases and fumes.

- Adequate engineering controls (i.e. ventilation).
- Adequate storage of hazardous materials.
- Obtain MSDS for all materials.
- Use appropriate PPE- lab coat, eye protection and gloves.
- Flammable: Appropriate storage of flammables.
- Solvents and reagents: Dyes should be treated as hazardous chemicals.
- Electrical hazards: Lethal electrical hazards are particularly present when high-power laser systems are used (i.e: Class 4). A neat electrical set-up is recommended to avoid accidents.
- Fire Hazard.
- Laser instruments with features that might require lockout tagout.

Best Work Practices for Laser Users

- When the laser beam is not enclosed, appropriate protective eyewear must be always worn.
- Use minimum power/energy required for project.
- Enclose the beam as much as possible by using protective housing, interlocks, non-combustible curtains and barriers.
- Reduce laser output with shutters/attenuators.
- All Class 4 lasers should have non-combustible beam stops.
- If possible, remote viewing systems during alignment.
- Remove unnecessary objects from vicinity of the laser.
- Beam path should be located at waist level and below. Not at eye level!
- Avoid putting body parts (especially eyes) in the beam path.

Laser Safety Eyewear

- **Optical Density (OD)** level at which the eyes are protected from a laser of a specific wavelength.
- Eyewear selection should be based on wavelength at which users work and/or highest wavelength capabilities.
- Do not use any eyewear without the optical density (OD) @ wavelength label on it.
- Do not use any damaged laser safety eyewear.
- Keep eyewear inside its case when not in use.

Program Scope

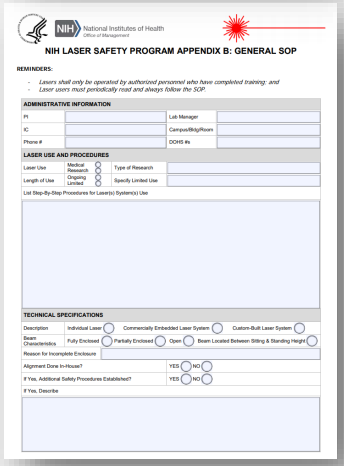
- **The NIH Laser Safety Program (LSP) provides guidance and oversight for the safe use of Class 3B and Class 4 lasers:**

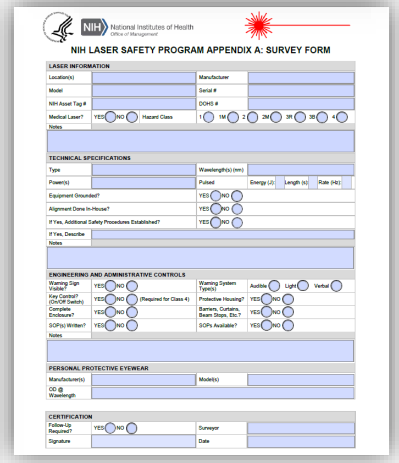
Class (IEC)	Description
3B	Medium-powered lasers (visible or invisible regions) that present a potential eye hazard for intrabeam (direct) or specular (mirror-like) conditions. Class 3B lasers do not present a diffuse (scatter) hazard or significant skin hazard except for higher powered 3B lasers operating at certain wavelength regions.
4	High-powered lasers (visible or invisible) considered to present potential acute hazard to the eye and skin for both direct (intrabeam) and scatter (diffused) conditions. Also have potential hazard considerations for fire (ignition) and byproduct emissions from target or process materials.

Program Scope and Requirements

Depending on the hazard class, set-up, and use of laser(s), the following may be required:

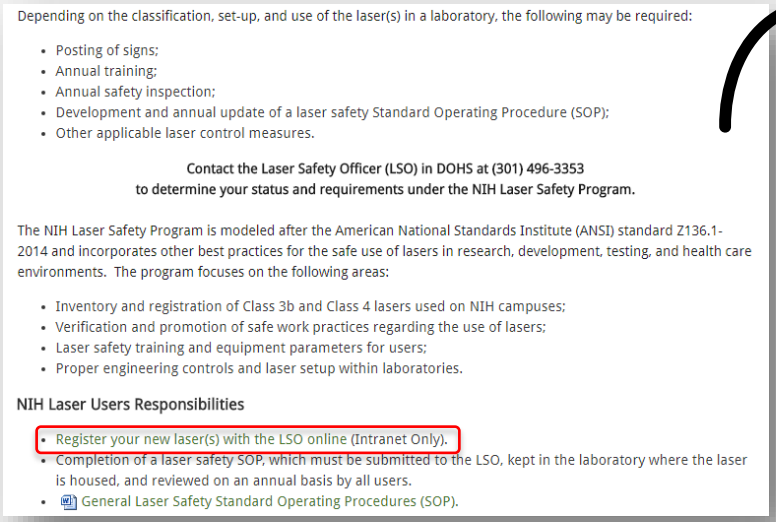
- Posting of warning signs
- Biennial training-every 2yrs
- Annual survey (new/modified set-up and high-risk lasers)
- Site-Specific SOPs
- Other applicable control measures





Requirements

- **All Class 3B and 4 Laser Acquisition/ Transfer: Laser Registration**
  - Require registration at time of purchase/transfer



Depending on the classification, set-up, and use of the laser(s) in a laboratory, the following may be required:

- Posting of signs;
- Annual training;
- Annual safety inspection;
- Development and annual update of a laser safety Standard Operating Procedure (SOP);
- Other applicable laser control measures.

Contact the Laser Safety Officer (LSO) in DOHS at (301) 496-3353
to determine your status and requirements under the NIH Laser Safety Program.

The NIH Laser Safety Program is modeled after the American National Standards Institute (ANSI) standard Z136.1-2014 and incorporates other best practices for the safe use of lasers in research, development, testing, and health care environments. The program focuses on the following areas:

- Inventory and registration of Class 3b and Class 4 lasers used on NIH campuses;
- Verification and promotion of safe work practices regarding the use of lasers;
- Laser safety training and equipment parameters for users;
- Proper engineering controls and laser setup within laboratories.

NIH Laser Users Responsibilities

- Register your new laser(s) with the LSO online (Intranet Only).
- Completion of a laser safety SOP, which must be submitted to the LSO, kept in the laboratory where the laser is housed, and reviewed on an annual basis by all users.
- General Laser Safety Standard Operating Procedures (SOP).

NIH National Institutes of Health
Office of Management

NIH Laser Safety Program - New Laser Registration

Please fill out as much information as possible.
After submission, the information will be reviewed by the Laser Safety Officer to determine if your laser(s) will be included in the NIH Laser Safety Program.
You will be contacted with the determination and additional instructions if necessary. Thank you!

Personnel Information

PRIMARY INVESTIGATOR (PI)

Name: * Email: *

IC: Select... * Campus: Select or type... * Building: * Room: *

LAB MANAGER (IF APPLICABLE)

Name: Email:

IC: Select... Campus: Select or type... Building: Room:

Total Number of Laser Users: 1-3 4-6 7+

Laser Information

Laser Signage per ANSI Guidelines

Class 4 DANGER Sign

REQUIRED:

This sign is required to mark at entryway(s) of areas containing Class 4 lasers with high (e.g., multi-kilowatt) output power or pulse energies with exposed beams.

This sign is rarely used. Please contact the LSO at (301) 496 - 2960 before use.

Class 3B and/or 4 WARNING Sign

REQUIRED:

This sign is required to mark at entryway(s) of areas containing Class 3B or Class 4 lasers (choose the highest class laser present in the area).

This sign is the most commonly used.

Temporary Area NOTICE Sign

REQUIRED:

This sign is required to mark at entryway(s) of areas that *temporarily* contain Class 3B or Class 4 lasers. This sign can be used during periods of service for lasers that are normally fully enclosed.

Class 2, 2M, and/or 3R CAUTION Sign

OPTIONAL:

This sign is optional for use to mark at entryway(s) of areas containing Class 2, Class 2M, or Class 3R lasers.

Embedded Laser Systems

Embedded Laser: a laser of a specific class that is reduced to a lower due to the mechanisms and devices(engineering controls) that remove potential for contact.

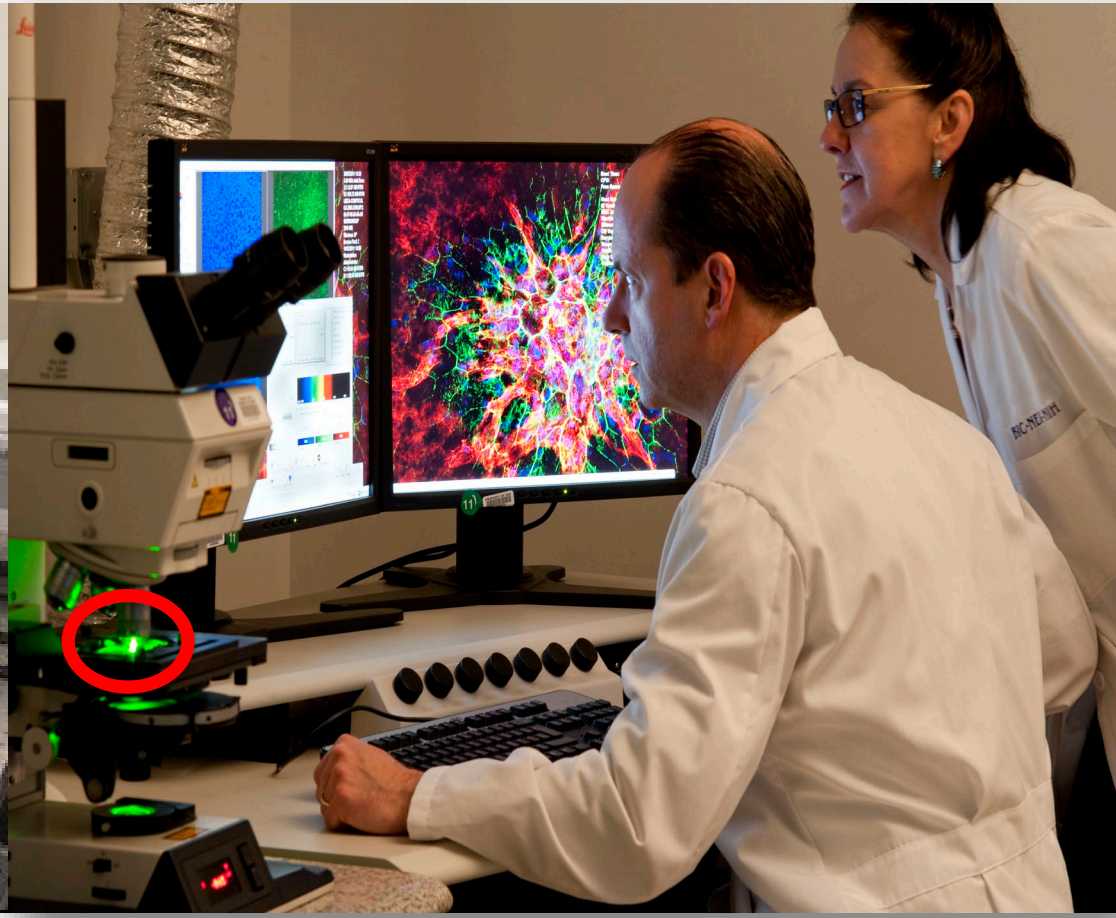
- Confocal
- TIRF microscopes
- Two-photon microscopes
- Cytometers
- Mass Spectrometers
- Laser Cutters

Important Note! *These systems typically have interlocks to prevent accidents due to beam exposure. If interlocks are bypassed, exposure or injury may occur. Additionally, once the enclosure is removed, the risk of injury becomes higher. At that point, it is important to remember to treat these systems as open beam lasers equipment.*

Requirements

- NIH LSP maintains records of these systems if they contain and are rated Class 3B or 4 power.
- Appropriate signage (Class 3B and 4) must be posted during service/alignment.
- Appropriate eye protection must be worn during service/alignment by all personnel in the laser space (including vendor performing service).
- Access must be restricted during servicing (e.g: **Laser repair in progress signage**)

Example of Confocal microscopes



Responsibilities of the Supervisors/PI

- Register new lasers online at https://go.usa.gov/xReGv (*accessible to users connected to the NIH network*).
- Identify all laser hazards and implement all appropriate hazard controls.
- Identify all personnel who may operate and/or maintain lasers and ensure training is completed.
- Maintain a copy of this written program in the workplace.
- Complete a Standard Operating Procedure (SOP) for each laser and posted at location(s).
- Report any major changes in laser operations to LSO (i.e: changes in laser set up/layout and laser location).
- Ensure laser users review manufacturer operating manual, technical specifications and guidelines of each laser equipment.

Responsibilities of Laser Users

- Know all hazards and associated procedures for the safe use of lasers in the work area;
- Complete required training(s) as specified by a supervisor/PI or LSO;
- Comply with the LSP and use good safety practices;
- Use all personal protective equipment as specified in prescribed training or required by a supervisor/PI or LSO; and
- Immediately notify a supervisor/PI or LSO of any hazards encountered and/or suspects that incident has occurred involving laser activities.

Responsibilities of the LSO

- Assist with laser hazard evaluation and verify laser equipment classification.
- Provide and/or facilitate laser safety training;
- Determine required safety practices and control measures critical for the implementation of a laser laboratory as specified by ANSI compliance with applicable laws and regulations;
- Consult on the purchase of necessary laser safety materials (signs, labels, safety eyewear, etc.);
- Conduct periodic reviews of the LSP, monitor and enforce program requirements.
- Develop and conduct laser safety surveys/inspections.

Emergency Procedures

In the event of a laser accident, immediately do the following:

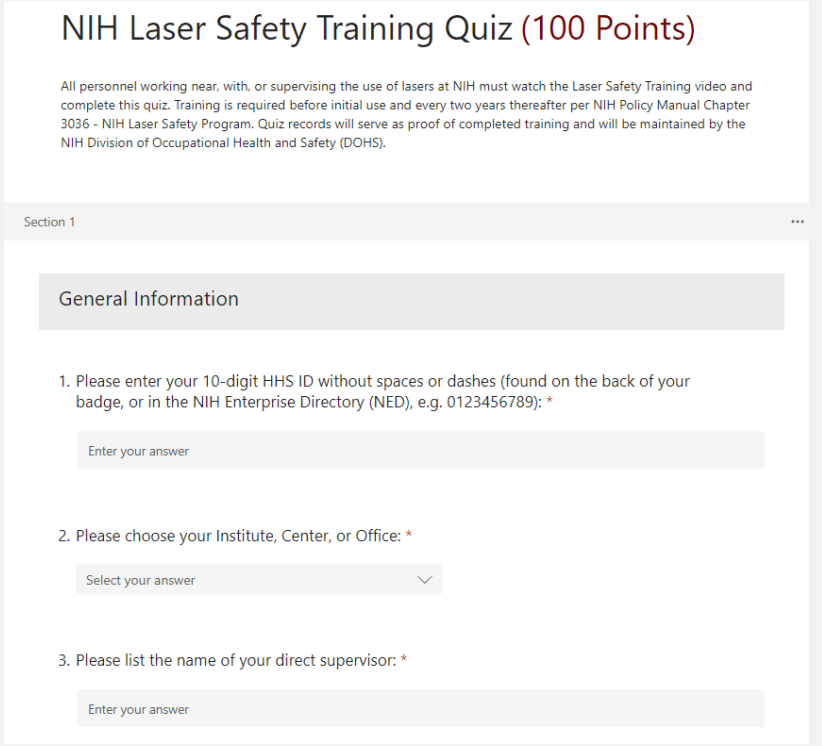
- Shut down the laser system.
- Provide for the safety of personnel (first aid, evacuation, etc.) as needed.
- Obtain medical assistance for anyone who may be injured.
- If there is a fire, leave the area, pull the fire alarm, and contact the fire department by calling the NIH emergency number, 911. Do not fight the fire unless it is very small and you have current fire extinguisher training.
- Inform the Principal Investigator as soon as possible. If there is an injury, the PI must submit a report of injury to the LSO.

Emergency Contact Numbers

- NIH Fire Department: 911 or 301- 496-2372.
- NIH Occupational Medical Service (OMS): 301-496-4000.
- Laser Safety Officer: 301-451-5993.
- Division of Occupational Health and Safety: 301-496-2960.

Laser Safety Training Quiz

- Complete the **Laser Safety Training Quiz.** (*Note: This link is only accessible on the NIH intranet).*
- There are 10 questions in the quiz, you will need a 70% to pass. Note that a certificate of completion will not be issued. However, we will maintain completion record.



NIH Laser Safety Training Quiz (100 Points)

All personnel working near, with, or supervising the use of lasers at NIH must watch the Laser Safety Training video and complete this quiz. Training is required before initial use and every two years thereafter per NIH Policy Manual Chapter 3036 - NIH Laser Safety Program. Quiz records will serve as proof of completed training and will be maintained by the NIH Division of Occupational Health and Safety (DOHS).

Section 1

General Information

1. Please enter your 10-digit HHS ID without spaces or dashes (found on the back of your badge, or in the NIH Enterprise Directory (NED), e.g. 0123456789): *

Enter your answer

2. Please choose your Institute, Center, or Office: *

Select your answer

3. Please list the name of your direct supervisor: *

Enter your answer

Resources

- NIH Laser Safety Website.
- Online Laser Registration (*Note: This link is only accessible on the NIH intranet)*
- SOP Template Form.
- lasersafety@mail.nih.gov .
- NIH Policy Manual Chapter 3036 - NIH Laser Safety Program.
- American National Standard (ANSI) Z136.1-2022- Safe Use of Lasers.
- FDA Laser Instruments and Products.
- Laser Institute of America- Laser Applications and Safety: https://www.lia.org/resources/laser-safety-information/laser-safety-standards/ansi-z136-standards/z136-1 .