University of North Texas

Basic Laser Safety Training

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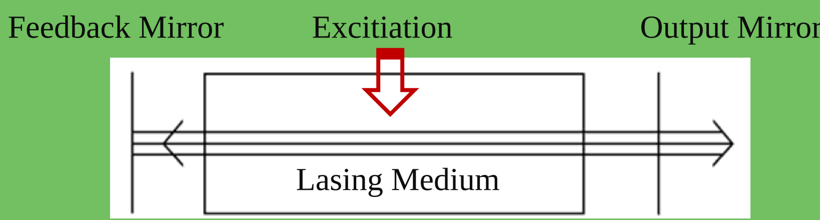
Fundamentals of Lasers: Basics

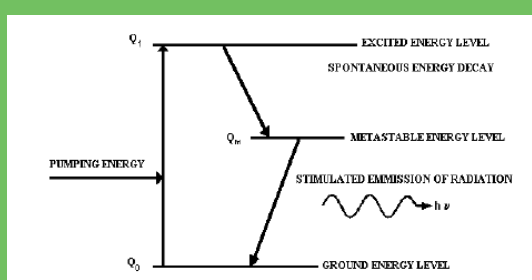
- The light emitted from a laser is monochromatic, directional, and coherent. These three properties of laser light are what can make it more hazardous than ordinary light. Laser light can deposit a lot of energy within a small area.
- Ordinary white light is a combination of many wavelengths of light, emits isotropically (in all directions), and is a mixture of many out-of-phase wavelengths.

Fundamentals of Lasers: Basics



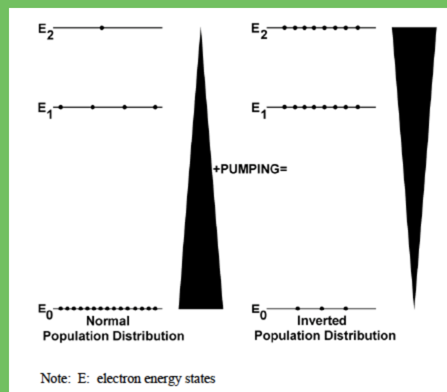
The Laser Medium can be gas, liquid, solid, or a semiconductor. Excitation can be performed optically, through electrons, or chemically pumped. The feedback mirror is a highly reflective mirror, and the Output mirror is a partially transparent mirror, allowing some of the light to escape.

Fundamentals of Lasers: Lasing



Energy is applied to a laser material through pumping, exciting the electrons to a high and unstable energy level. The atom or moleculaes of the media spontaneously decay to a relatively long-lived, lower energy, metastable state. Pumping continues to increase the number in this metastable state.

Fundamentals of Lasers: Lasing



The lasing material is continually pumped, increasing the metastables, until the number of metastables exceeds the lower level of the normal population. This is called population inversion. Once population inversion is reached, lasing is possible.

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Fundamentals of Lasers: Pumping

Examples of pumping systems are:

1. Optical pumping – utilization of an intense light source to reach excited state. (Argon, Diode lasers)

2. Electron pumping – Electron bombardment or electric current through the laser material to reach excited state. (Helium-Neon Lasers)

3. Chemical pumping – Energy is released in the making and breaking of bonds. (HF lasers)

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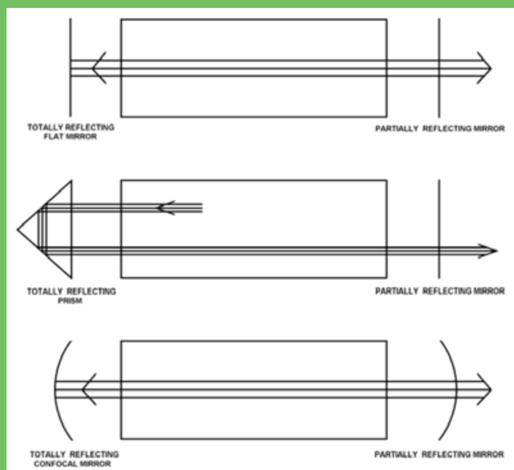
Fundamentals of Lasers: Laser Components



Shown are 3 typically optical cavities. The optical cavity is restricted within mirrors to allow the photons to pass through he medium many time to amplify. Beams are transmitted out mirrors with partial reflection.

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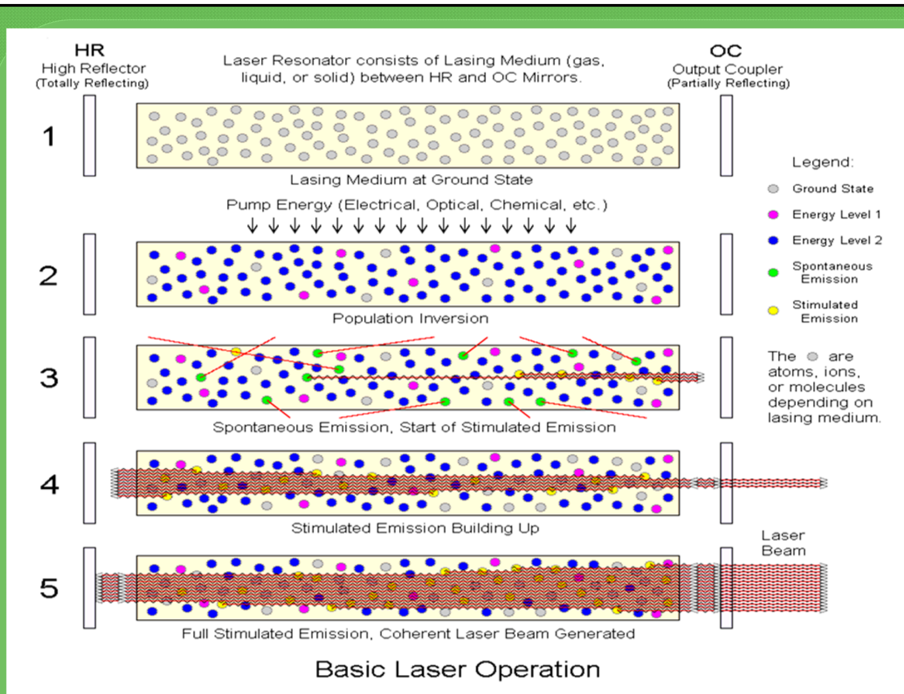

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Fundamentals of Lasers: Common Lasers

Common laser wavelengths[1]

CIE band	Wavelength nm	Medium	Typical Operation
UV-C, B, A[2]	193, 222, 248, 308, 351	Excimer	CW/Pulsed
UV-A	325	Helium-cadmium	CW
UV-A	327	Nitrogen	Repetitively pulsed
UV-A	350	Argon	CW
Visible light	441.6	Helium-Cadmium	CW
Visible light	458 ,488 ,514.5	Argon	CW
Visible light	568, 647	Krypton	CW
Visible light	532	Nd:YAG frequency-doubled	Pulsed
Visible light	511-578	Copper vapor	Repetitively pulsed
Visible light	632.8	Helium-neon	CW
Visible light	670	Diode	CW
Visible light	694.3	Ruby	Pulsed
Visible light	560-640	Rhodamine 6G dye	CW/Pulsed
IR-A[3]	700-800	Alexandrite	Repetitively pulsed
IR-A	850	GaA1As[4]	Repetitively pulsed
IR-A	905	Gallium-arsenide	Repetitively pulsed
IR-A	1060	Nd:glass	Pulsed
IR-A	1064	Nd:YAG[5]	Pulsed
IR-B[6]	1540	Erbium:YAG	Pulsed
IR-B	2900	Hydrogen fluoride	Pulsed
IR-C	3900	Deuterium fluoride	Pulsed
IR-C[7]	10,600	Carbon dioxide	CW

Notes:
[1] Source: Modified from Field Manual (FM) 8-50, table A-1
[2] Ultraviolet radiation:
(a) UV–C (100 nm–280 nm)
(b) UV–B (280 nm–315 nm)
(c) UV–A (315 nm–400 nm)
[3] IR–A (700 nm–1400 nm)
[4] GaA1As: Gallium Aluminum Arsenide
[5] Nd:YAG: Neodymium:Yittrium Aluminum Garnet
[6] IR–B (1400 nm–3 micrometer (μm))
[7] IR–C (3 μm–1000 μm)

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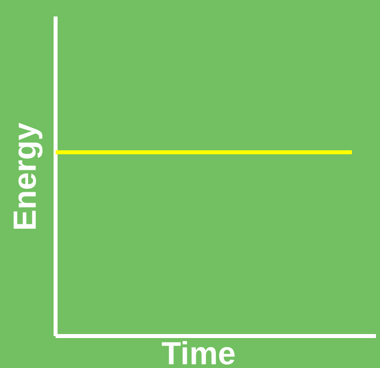
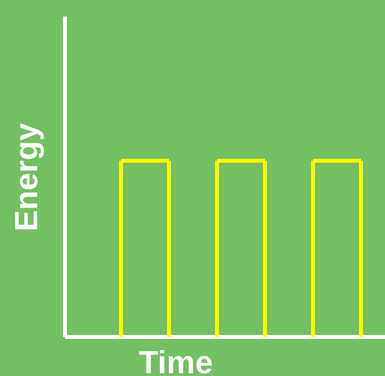
Fundamentals of Lasers: Types of Output



Continuous Wave (CW) Lasers put out a continuous beam with a constant energy for a prescribed period of time



Pulsed Lasers put out a discrete amount of energy in bursts with regulation in frequency (Hz) and pulse duration (femtoseconds – microseconds)

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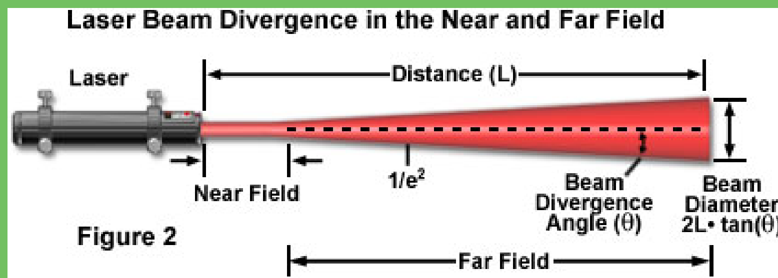
Fundamentals of Lasers



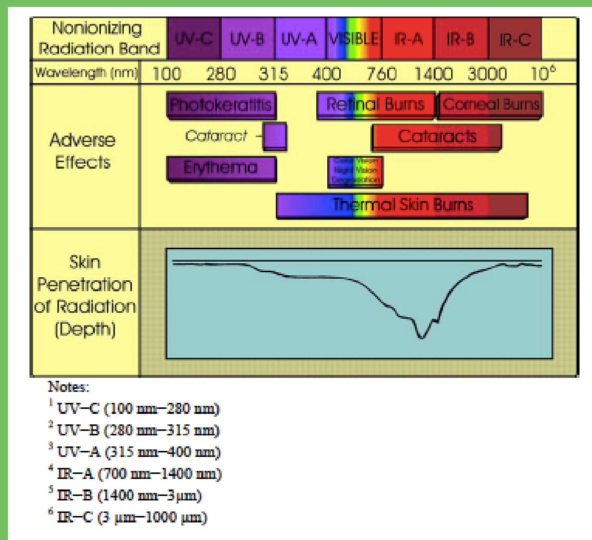
Laser Bioeffects: Damage

Primary Sites of Beam Damage are:
1. Skin
2. Eyes

Laser beams can cause:
1. Heat damage (thermal)
2. Acoustic damage(sound)
3. Photochemical damage

Other damages:
1. Chemical from laser medium (gas release, handling)
2. Electrical Shock (some lasers have intense and powerful electrical sources)

Laser Bioeffects: Damage



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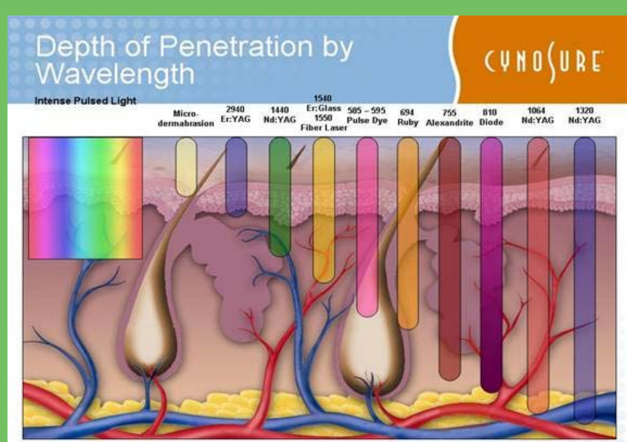
Laser Bioeffects: Skin Damage



Skin damage occurs from exposure to UV-B, UV-A, Visible, IR-A, and IR-B. The greatest penetration depth from IR-A (ex. Nd:YAG 1064nm and 1320nm)

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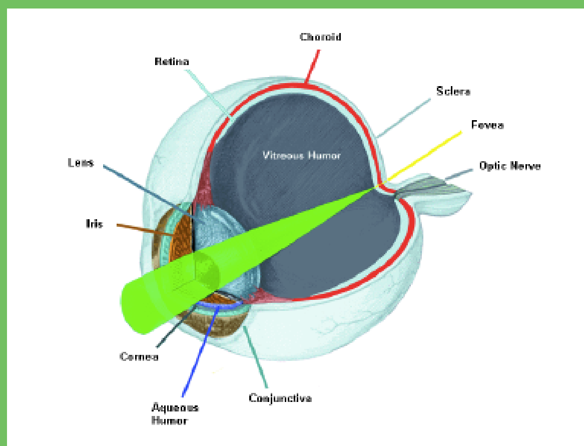
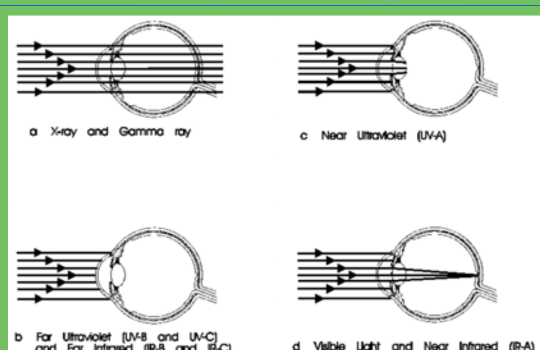
Laser Bioeffects: Eye Damage



Adverse effect from laser exposure can cause Retinal Burns and Corneal Burns which will lead to loss of sight, Cataracts

Laser Bioeffects: Eye Damage



(a) X-Rays and Gamma Rays have minimal eye adsorption, (b) UV-B, UV-C, IR-B, and IR-C radiation effect primarily the Cornea, (c) UV-A is adsorbed primarily on the Lens, and (d) Visible and IR-A is adsorbed on the Retina and in the Ocular Media.

Laser Bioeffects: Eye Damage

1. Exposure to the invisible ***carbon dioxide laser*** beam (10,600 nm) can be detected by a burning pain at the site of exposure on the cornea or sclera.
2. Exposure to a visible laser beam can be detected by a bright color flash of the emitted wavelength and an after-image of its complementary color (e.g., a green 532 nm laser light would produce a green flash followed by a red after-image).
3. When the retina is affected, there may be difficulty in detecting blue or green colors secondary to cone damage, and pigmentation of the retina may be detected.
4. Exposure to the ***Q-switched Nd:YAG laser*** beam (1064 nm) is especially hazardous and may initially go undetected because the beam is invisible and the retina lacks pain sensory nerves.
5. ALL COULD LEAD TO BLINDNESS!!

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Laser Bioeffects: Hazards

Other damages:
1. Chemical from laser medium (gas release, handling)
2. Electrical Shock (some lasers have intense and powerful electrical sources)

Be mindful of the postings to understand other Hazards !

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Laser Classifications: ANSI

American National Standards Institute (ANSI) laser class is based on AEL (Accessible Emission Limit) thresholds

Class 1 lasers or systems cannot emit accessible laser radiation in excess of the applicable Class 1 AEL for any exposure times within the maximum duration inherent in the design or intended use of the laser. Class 1 lasers are exempt from all beam-hazard control measures.
Class 2 lasers are CW and repetitively pulsed lasers with wavelengths between 0.4 µm and 0.7 µm that can emit energy in excess of the Class 1 AEL, but do not exceed the Class 1 AEL for an emission duration less than 0.25 seconds and have an average radiant power of 1mW or less.
Class 3a lasers have an accessible output between 1 and 5 times the Class 1 AEL for wavelengths shorter than 0.4 µm or longer than 0.7 µm, or less than 5 times the Class 2 AEL for wavelengths between 0.4 µm and 0.7 µm.
Class 3b lasers cannot emit an average radiant power greater than 0.5 Watts for an exposure time equal to or greater than 0.25 seconds or 0.125 Joules for an exposure time less than 0.25 seconds for wavelengths between 0.18 µm and 0.4 µm, or between 1.4 µm and 1 mm. In addition, lasers between 0.4 µm and 1.4 µm exceeding the Class 3a AEL cannot emit an average radiant power greater than 0.5 Watts for exposures equal to or greater than 0.25 seconds, or a radiant energy greater than 0.03 Joules per pulse.
Class 4 lasers and laser systems exceed the Class 3b AEL.

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Laser Classifications: CDRH

Center for Devices and Radiological Health (CDRH) laser class is based on Potential for Causing Biological Damage

Class I laser product means any laser product that does not permit human access during the operation to levels of laser radiation in excess of the accessible emission limits as defined in Table I of 21 CFR Subchapter J Part 1040.10. Class I levels of laser radiation are not considered to be hazardous.
Class II laser product means any laser product that permits human access during operation to levels of visible laser radiation in excess of the accessible emission limits contained in Table II-A of 21 CFR Subchapter J Part 1040.10, but does not permit human access during operation to levels of laser radiation in excess of the accessible emission limits contained in Table II of 21 CFR Subchapter J Part 1040.10. Class II levels of laser radiation are considered to be a chronic viewing hazard.
Class IIIa laser product means any laser product that permits human access during operation to levels of visible laser radiation in excess of the accessible emission limits contained in Table II of 21 CFR Subchapter J Part 1040.10, but does not permit human access during operation to levels of laser radiation in excess of the accessible emission limits contained in Table III-A of 21 CFR Subchapter J Part 1040.10. Class IIIa levels of laser radiation are considered to be, depending upon the irradiance, either an acute intrabeam viewing hazard or chronic viewing hazard, and an acute viewing hazard if viewed directly with optical instruments.

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Laser Classifications: CDRH

Center for Devices and Radiological Health (CDRH) laser class is based on Potential for Causing Biological Damage

Class IIIb laser product means any laser product that permits human access during operation to levels of laser radiation in excess of the accessible emission limits of Table III-A, but does not permit human access during operation to levels of laser radiation in excess of the accessible emission limits contained in Table III-B of 21 CFR Subchapter J Part 1040.10. Class IIIb levels of laser radiation are considered to be an acute hazard to the skin and eyes from direct radiation. Class IIIb laser products may have removable panels that, when displaced, permit access to levels of laser radiation ranging from Class II to Class IV.

Class IV laser product means any laser that permits human access during operation to levels of laser radiation in excess of the accessible emission limits contained in Table III-B of 21 CFR Subchapter J Part 1040.10. Class IV levels of laser radiation are considered to be an acute hazard to the skin and eyes from direct and scattered radiation. Class IV laser products may have removable panels that, when displaced, permit access to levels of laser radiation ranging from Class II to Class IV.

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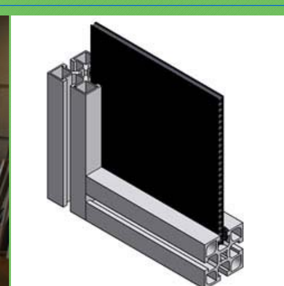
Laser Control Methods: Confinement



Laser Enclosures and Isolated Rooms are the best way to protect against stray light. Open laser experiments should be avoided unless absolutely necessary.

Laser Interlocks connected to the laser and enclosure should be implemented in possible. These will cause the laser to shutdown if compromised.

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Laser Control Methods: Awareness

Be Aware of All Postings. Assume the Lasers are active and take proper precautions always.

Rooms and Laboratories with Working Class 2-4, or II-IV should have illuminated lights outside, telling if experiments are in progress. These Rooms should never be entered without proper safety precautions. Remember, stray laser light can escape once the door in compromised.

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Laser Control Methods: Safety Googles

Laser Protective eyewear is selected based on the maximum protection for the laser of use, while still maintaining visible sight and comfort. The wearer must always be cognizant that the goggles will reduce visibility.

Laser Protective Eyewear <u>must always</u> be worn for Class 2-4, and Class II-IV

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Laser Control Methods: Safety Googles

Optical density. OD is a parameter for specifying the attenuation afforded by a transmitting medium. Since laser beam irradiances may be a factor of a thousand or a million above safe exposure levels, percent transmission notation can be tedious.

For instance, goggles with a transmission of 0.000001 percent can be described as having an OD of 8.0. OD is a logarithmic expression and is described by the following:

$$OD = \log10 (Mi/Mt)$$

Where: Mi is the power of the incident beam and Mt is the power of the transmitted beam.
Thus, a filter that attenuates a beam by a factor of 1,000 has an OD of 3, and one that attenuates a beam by 1,000,000 or 106 has an OD of 6.

Laser Control Methods: Safety Googles

Laser Protective Eyewear should always be stamped with the OD rating and the wavelengths it will protect. For best visibility, use the Goggle set specific for the laser beam used.

Again, Laser Protective Eyewear <u>must always</u> be worn for Class 2-4, and Class II-IV

Laser Control Methods: Proper Skin Coverage

For Skin Protection, it is preferable to wear long sleeves when working with a Class 3-4, or III-IV laser. Be sure the sleeves are cuffed to avoid the loose clothing bumping the optics.

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Laser Safety Contact: UNT Risk Management

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