Laser Therapy

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Laser Therapy

Objectives

After completing this topic, the physiotherapy student will be able to;

- ✓ State the characteristics of laser beam.
- ✓ Describe the characteristics of helium neon and gallium arsenide low-power lasers.
- ✓ Describe physiological effects and therapeutic uses of low-power laser.
- ✓ Demonstrate the application techniques of low-power lasers.
- ✓ Identify the dangers and contraindications of laser.

Laser Therapy

Content

- ✓ Introduction
- ✓ Physics
- ✓ Properties of laser
- ✓ Components for laser production
- ✓ Types of laser
- ✓ Techniques of application
- ✓ Dosage parameters
- ✓ Depth of Penetration
- ✓ Interaction of laser with body tissues
- ✓ Physiological effects and therapeutic uses of laser
- ✓ Dangers and Contraindications

Laser Therapy

Introduction

- Laser is an acronym for light amplification of stimulated emission of radiation.

- A laser is a form of electromagnetic energy that has wavelengths and frequencies that fall within the infrared and visible light portions of the electromagnetic spectrum.

Laser Therapy

Physics

- Electromagnetic light energy is transmitted through space as waves that contain tiny "energy packets" called photons.
- Each photon contains a definite amount of energy, depending on its wavelength (color).
- A laser consists of a gain medium, which is a material (gas, liquid, solid) with specific optical properties contained inside an optical chamber.
- When an external power source is applied to the gain medium, photons are released
- which are identical in phase, direction, and frequency.

Laser Therapy

Physics

- To contain them, and to generate more photons, mirrors are placed at both ends of the chamber. One mirror is totally reflective, whereas the other is semitransparent.
- The photons bounce back and forth reflecting between the mirrors, each time passing through the gain medium thus amplifying the light and stimulating the emission of other photons.

Laser Therapy

Physics

- Eventually, so many photons are stimulated that the chamber cannot contain the energy.
- When a specific level of energy is attained, photons of a particular wavelength are ejected through the semitransparent mirror appearing as a beam of light.
- Thus, amplified light through stimulated emissions (**laser**) is produced.

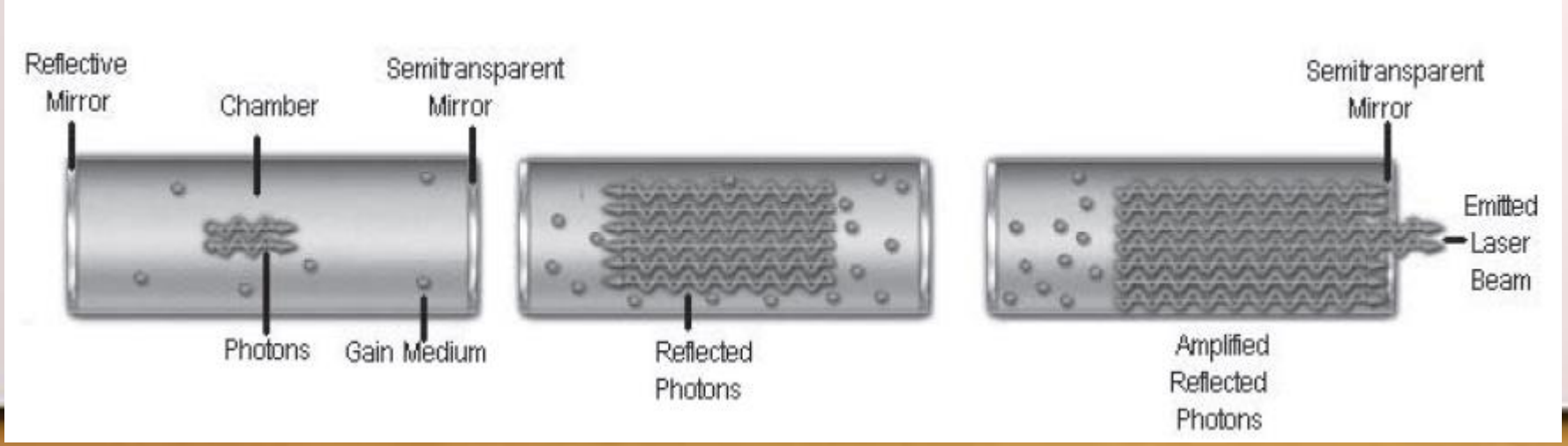

Figure A laser produces amplified light through stimulated emissions.

Laser Therapy

Physics

- The laser light is emitted in an organized manner rather than in a random pattern as from incandescent and fluorescent light sources.
- Three properties distinguish the laser: coherence, monochromaticity, and collimation.

photon The basic unit of light; a packet or quanta of light energy.

gain medium A material (gas, liquid, solid) with specific optical properties contained inside an optical chamber.

stimulated emission This occurs when photons are ejected through the semitransparent mirror appearing as a beam of light

Laser Therapy

Properties
1. Monochromaticity
2. Coherence
3. Collimation

Properties of Laser

1. Monochromaticity
   - This means that the laser light has a single color (mono-single, chromaticity-coloration).
   - This is because the lasers are of a single wavelength and thus the definite frequency.
   - Ordinary light however has many wavelengths.

Properties of Laser

2. Coherence
   - All photons of light emitted from individual gas molecules are the same wavelength and that the individual light waves are in phase with one another.
   - Normal light, on the other hand, is composed of many wavelengths that superimpose their phases on one another.
3. Collimation
   - Laser beams remain collimated that means they remain in parallel.
   - They do not diverge much and the energy can be propagated over a larger distance.

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Properties
1. Monochromaticity
2. Coherence
3. Collimation

Properties of Laser

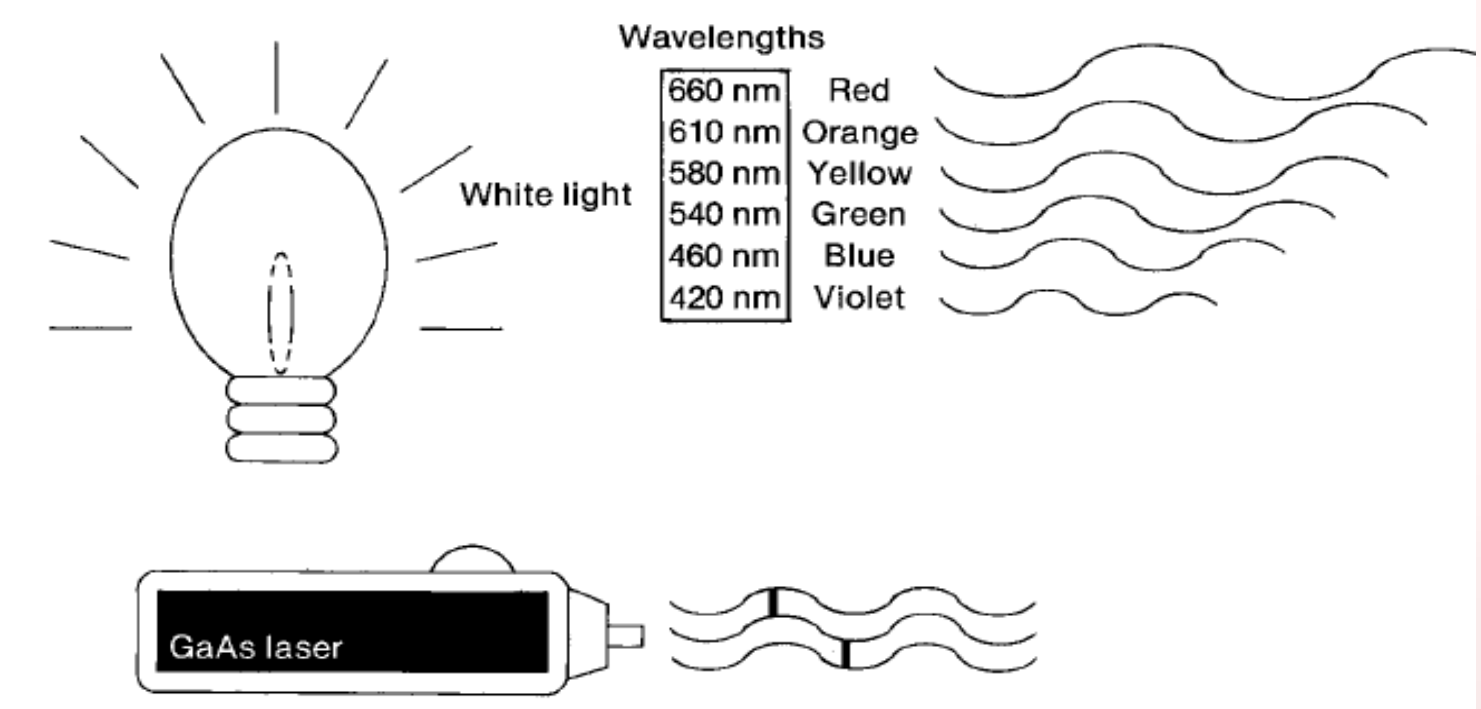

Figure ***Top.*** White light contains electromagnetic energy of all wavelengths (colors) that are superimposed on each other. ***Bottom.*** Laser light is monochromatic (single wavelength), coherent (in phase), and collimated (minimal divergence)

Laser Therapy

The device must consist of:
1. Lasing medium
2. Resonating chamber
3. Energy source

Components for Laser Production

1. Lasing medium
   - The material which is capable of producing laser is known as lasing medium.
   - It can absorb energy from the external source and then gives off its excess energy as photons of light.
   - Lasing medium could be solid crystal or semiconductor, liquid or gas.
   - The lasing media in low intensity laser or cold laser are either helium-neon (He-Ne) or semiconductor (Ga-As).

Laser Therapy

The device must consist of:
1. Lasing medium
2. Resonating chamber
3. Energy source

Components for Laser Production

2. Resonating chamber:

- The resonating chamber contains the lasing medium which is surrounded by two parallel mirrors at either ends.
- One of the mirrors has 100% reflectance while the other has slightly less reflectance.
- The mirror with slightly less reflectance serves as an output device which allows some of the photons to escape through it.

Laser Therapy

The device must consist of:
1. Lasing medium
2. Resonating chamber
3. Energy source

Components for Laser Production

3. Energy source

- A flashgun is used to excite the electrons of the lasing medium.
- The source of flashgun is usually current electricity.

Laser Therapy

Types
1. Ruby laser (or crystal laser)
2. Helium-neon laser (gas laser)
3. Diode laser (semiconductor laser)

Types of Laser

1. Ruby Laser (Crystal Laser)
   - It contains synthetic ruby (aluminium oxide and chromium) as a lasing medium.
   - Aluminum oxide with trace of chromium oxide forms a 10 cm long and 1 cm wide synthetic ruby rod.
   - A helical electric discharge tube containing xenon tube is wound around the ruby rod.
   - Both the ends are made reflecting by silvering the surfaces with one end as 100% reflective and other slightly less.

Laser Therapy

Types
1. Ruby laser (or crystal laser)
2. Helium-neon laser (gas laser)
3. Diode laser (semiconductor laser)

Types of Laser

1. Ruby Laser (Crystal Laser)
   - The xenon tube is used to give intense flash of white light which excites the ruby molecules and raises the electron to a higher energy level.
   - As the excited state is unstable, the electrons return to ground state by releasing a photon. This is known as spontaneous emission.

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Types of Laser

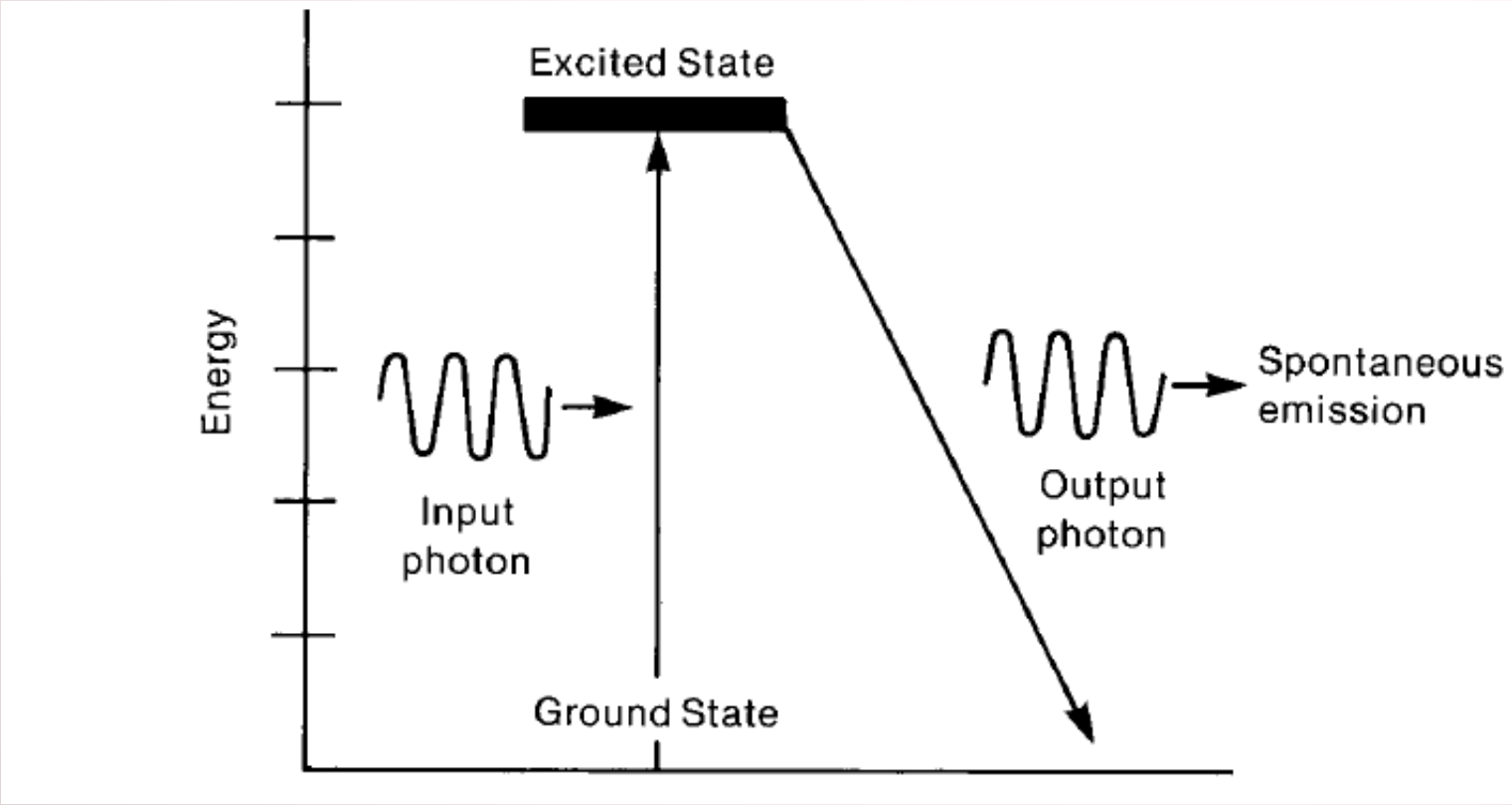

Figure Spontaneous emission occurs when a photon changes energy level

Types of Laser
1. Ruby laser (or crystal laser)
2. Helium-neon laser (gas laser)
3. Diode laser (semiconductor laser)

Types of Laser

1. Ruby Laser (Crystal Laser)
   - The rate of supply of energy exceeds to a greater extent which leads to a large number of atoms at higher energy levels. This is known as population inversions.
   - Atoms in their excited state are encountered by the photons and this leads to further stimulated emissions.
   - The excited electron falls to its resting state and gives off a photon of exactly the same energy as that of photon which collided with it (photon of 694.3 nm wavelength).
   - Hence, **a beam of red laser** with **a wavelength 694.3 nm** is emitted.

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Types of Laser

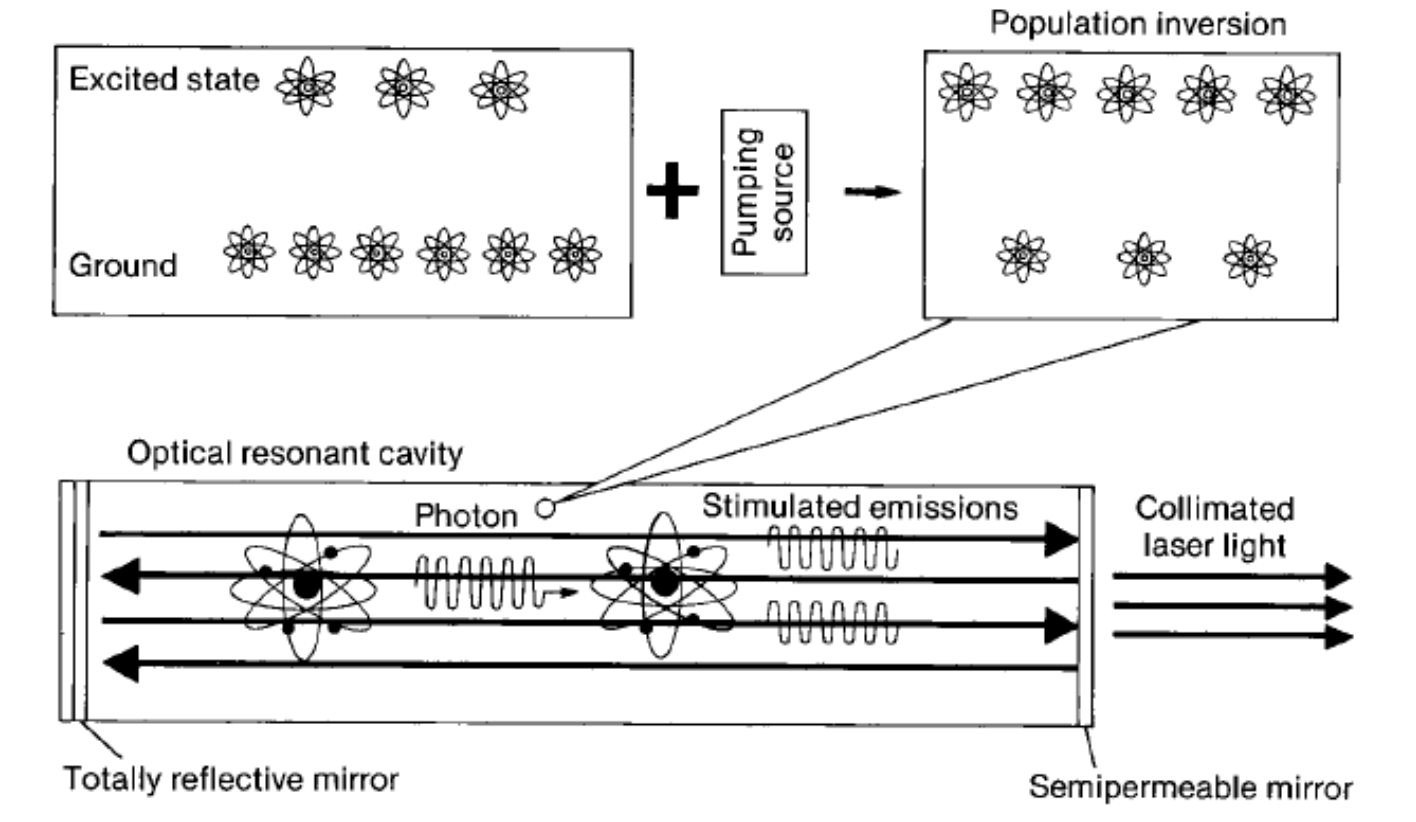


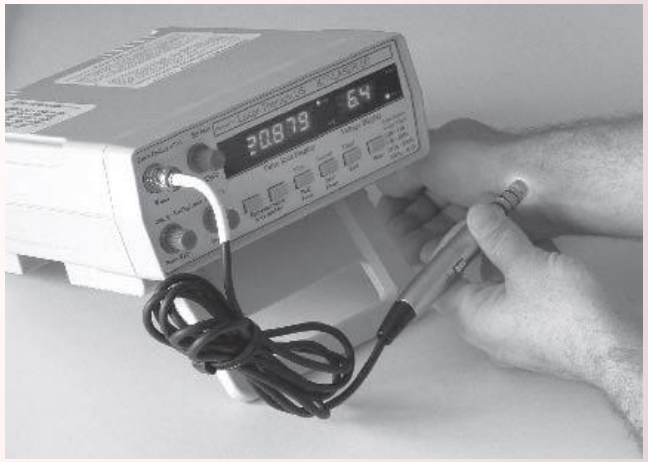
Figure Pumping is a process of elevating an orbiting electron to a higher level, thus creating population inversion, which is essential for laser operation

Types of Laser
1. Ruby laser (or crystal laser)
2. Helium-neon laser (gas laser)
3. Diode laser (semiconductor laser)

Types of Laser

2. Helium-neon Laser (Gas Laser)

- Gas laser consists of a mixture of primarily helium and neon in a low pressure tube.
- This low pressure tube is surrounded by a flashgun which excites the atom to a higher energy level.
- Thus, photons released by the spontaneous emission and have a wavelength of 632.8 nm.



Helium neon laser

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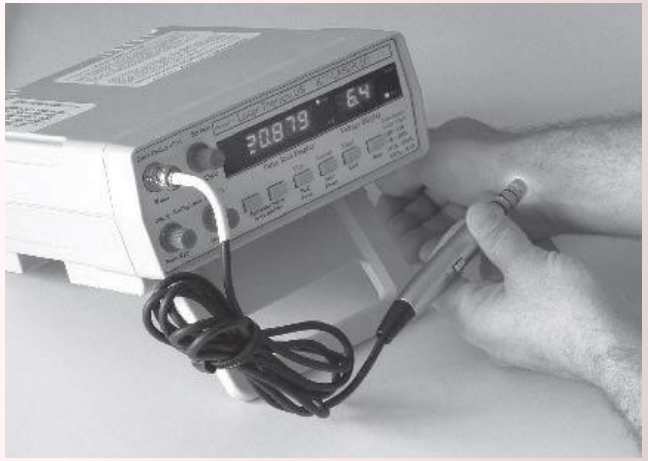
Types of Laser
1. Ruby laser (or crystal laser)
2. Helium-neon laser (gas laser)
3. Diode laser (semiconductor laser)

Types of Laser

2. Helium-neon Laser (Gas Laser)
   - These photons reflect to and fro to the tube and collide with the atoms of higher energy levels.
   - This leads to stimulated emission with the release of similar photons.
   - Intense beam of light emerges from the narrow partially transmissive which is **red in color** and has **a wavelength of 632.8 nm**.



Helium neon laser

Types of Laser
1. Ruby laser (or crystal laser)
2. Helium-neon laser (gas laser)
3. Diode laser (semiconductor laser)

Types of Laser

3. Diode Laser (Semiconductor Laser)
   - Gallium and arsenide are used as a diode or semiconductor to produce **an infrared invisible laser with a wavelength of 904 nm.**
   - An external electric potential, positively charged ‘holes’ are thrown from the p-type gallium-aluminium-arsenide layer into the active layer of gallium-arsenide.
   - The negatively charged electrons interact with the active layer and thus photon of light is released.

Gallium arsenide laser

Laser Therapy

Types of Laser

1. Ruby laser (or crystal laser)
2. Helium-neon laser (gas laser)
3. Diode laser (semiconductor laser)

Types of Laser

3. Diode Laser (Semiconductor Laser)
   - The photons are reflected to and fro and emitted as a laser beam from one partially transparent end.
   - By varying the ratio of gallium to aluminium, desired specific wavelengths are obtained.
   - The advantage of semiconductor laser diode is that these **can either emit a continuous or a pulsed output.**

Gallium arsenide laser

Laser Therapy

Types of Laser
1. Ruby laser (or crystal laser)
2. Helium-neon laser (gas laser)
3. Diode laser (semiconductor laser)

Types of Laser

Table Parameters of low-output lasers

	Helium Neon (HeNe)	Gallium Arsenide (GaAs)
Laser type	Gas	Semiconductor
Wavelength	632.8 nm	904 nm
Pulse rate	Continuous wave	1–1000 Hz
Pulse width	Continuous wave	200 nsec
Peak power	3 mW	2 W
Average power	1.0 mW	0.04–0.4 mW
Beam area	0.01 cm	0.07 cm
FDA class	Class II laser	Class I laser

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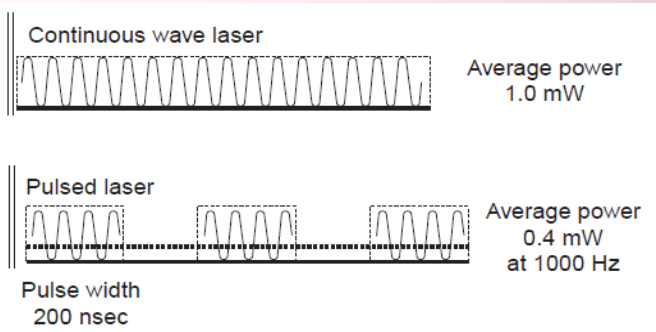

Figure 1: Continuous wave versus pulsed energies.

Laser Therapy

Techniques
1. Grid method
2. Scanning method.

Techniques of Application

- Generally, the laser energy is emitted by a hand held applicator for therapeutic purposes.
- The gallium-arsenide laser contains the semiconductor or diode element at the tip of the applicator.
- The helium-neon laser contains their components inside the unit and delivers the laser light to the target area via a fiberoptic tube. This causes divergence of the beam.

Laser Therapy

Techniques
1. Grid method
2. Scanning method.

Techniques of Application

1. Gridding Technique

- The treatment area is divided into a grid each of 1 square cm.
- The hand held applicator should be in light contact with the skin and directly perpendicular to the target tissue.
- Each square cm is stimulated for a specific period of time.

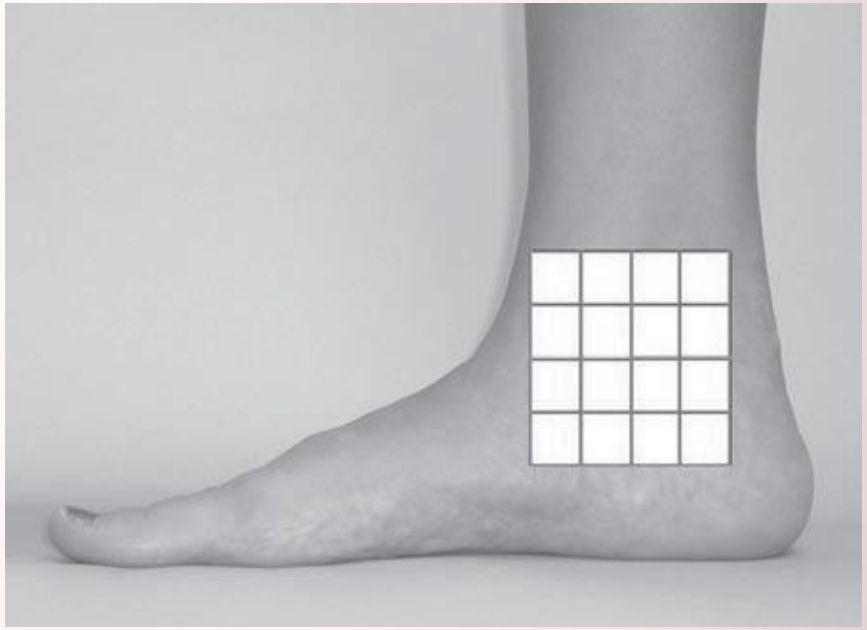

Figure 2: Gridding technique. An imaginery grid should be drawn over the area to be treated and each square centimeter of the injured area should be lasered for the specified time. The laser should be in light contact with the skin.

Laser Therapy

Techniques

1. Grid method
2. Scanning method.

Techniques of Application

2. Scanning Technique

- No contact is made between the tip of the laser and the patient's skin.
- The tip of the applicator is held at a distance of 5 to 10 mm.
- Since the divergence of beam occurs, there is a decrease in the amount of energy applied as the distance increases.

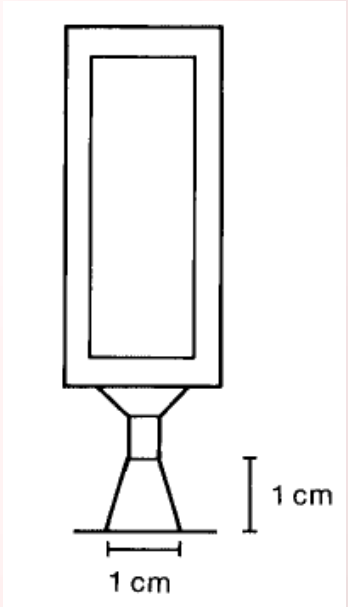

Figure 3: Scanning technique. When skin contact cannot be maintained, the application should be held in the center of the square centimeter grid at a distance of less than1 cm and should be at an angle of 30° to the surface being treated.

Laser Therapy

Dosage Parameters
1. Wavelength
2. Power
3. Energy
4. Power density
5. Energy density

Dosage Parameters

1. Wavelength

- Wavelength depends on the lasing medium used.
- For superficial conditions like wounds and ulcers, visible red laser is used.
- For deep conditions of muscles and bones, infrared laser is used.
- Cluster probe laser having several diodes are used for the larger area of soft tissues.

Dosage Parameters

2. Power

- The power output is measured in Watts (W). Since the power output of laser beam used therapeutically is quite small, mW is generally used.
- Moreover, percentage of power output is sometimes used, i.e. 10, 20 or 30% of the total power output.

Dosage Parameters

3. Energy

- The energy delivered to the treatment tissue is expressed in Joules and is calculated by :

  Energy (in Joules) = Power (in Watts) × Time (in seconds)

- Sometimes, when the energy required for the treatment of a particular tissue is known and the power output is available then the total treatment time can also be calculated.

Dosage Parameters

4. Power density

- Power density decreases as the area between the tip of the applicator and the part to be treated increases and is expressed as:

Power density = Incident power/area in cm2

- Total power used therapeutically is thus calculated by the inverse square law.

Dosage Parameters

5. Energy density

- Energy density can be calculated as:

$$\text{Energy density} = \frac{\text{Power (W)} \times \text{Time (sec)}}{\text{Area (in cm}^2\text{)}}$$

- The dosage in laser therapy is calculated in terms of energy density applied which is expressed in Joules/cm2.

Laser Therapy

Dosage Parameters

Table Treatment times for low-output lasers

Laser Type	Average Power (mW)	Joules per Centimeter Squared (J/cm^2)						
		0.05	0.1	0.5	1	2	3	4
HeNe (632.8 nm) continuous wave	1.0	0.5	1.0	5.0	10.0	20.0	30.0	40.0
GaAs (904 nm) pulsed at 1000 Hz	0.4	8.8	17.7	88.4	176.7	353.4	530.1	706.9

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Dosage Parameters

Table Suggested treatment applications

Application	Laser Type	Energy Density
Trigger point		
Superficial	HeNe	1-3 J/cm^2
Deep	GaAs	1-2 J/cm^2
Edema reduction		
Acute	GaAs	0.1-0.2 J/cm^2
Subacute	GaAs	0.2-0.5 J/cm^2
Wound healing (superficial tissues)		
Acute	HeNe	0.5-1 J/cm^2
Chronic	HeNe	4 J/cm^2
Wound healing (deep tissues)		
Acute	GaAs	0.05-0.1 J/cm^2
Chronic	GaAs	0.5-1 J/cm^2
Scar tissue	GaAs	0.5-1 J/cm^2

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Laser Therapy

Depth of Penetration

- Any energy applied to the body can be absorbed, reflected, transmitted, and refracted.
- Biologic effects result only from the absorption of energy, and as more energy is absorbed, less is available for the deeper and adjacent tissues.
- Laser light's depth of penetration depends on the type of laser energy delivered

direct effect The tissue response that occurs from energy absorption.

indirect effect A decreased response that occurs in deeper tissues.

Laser Therapy

	Depth of Penetration	
Types of Laser	Direct effect	Indirect effect
HeNe (632.8 nm)	2–5 mm	8–10 mm
GaAs (904 nm)	1–2 cm	5 cm

Depth of Penetration

- Absorption of HeNe laser energy occurs rapidly in the superficial structures, especially within the first 2–5 mm of soft tissue.
- The response that occurs from absorption is termed the direct effect.
- The indirect effect is a lessened response that occurs deeper in the tissues. The normal metabolic processes in the deeper tissues are catalyzed from the energy absorption in the superficial structures to produce the indirect effect.
- HeNe laser has an indirect effect on tissues up to 8–10 mm.

Laser Therapy

	Depth of Penetration	
Types of Laser	Direct effect	Indirect effect
HeNe (632.8 nm)	2–5 mm	8–10 mm
GaAs (904 nm)	1–2 cm	5 cm

Depth of Penetration

- The GaAs, is directly absorbed in tissues at depths of 1–2 cm and has an indirect effect up to 5 cm.
- The radius of the energy field expands as the nonabsorbed light is reflected, refracted, and transmitted to adjacent cells as the energy penetrates.
- The clinician should stimulate each square centimeter of a "grid".

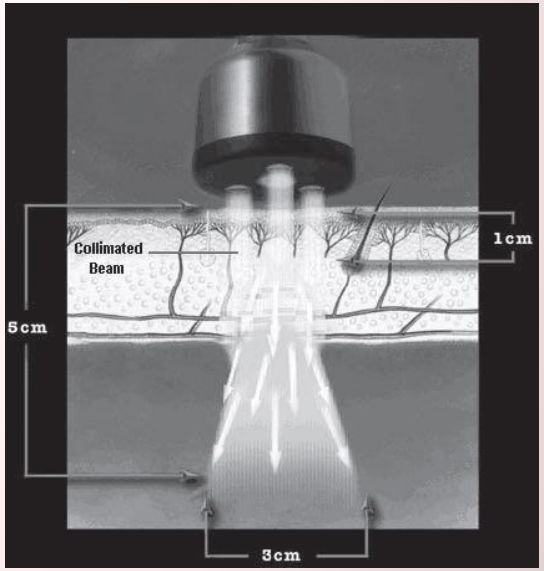

Figure Depth of penetration with a GaAs laser. Direct penetration is up to 1 cm with the collimated laser beam. Stimulation causes indirect effects up to 5 cm.

Laser Therapy

Interaction of Laser with Body Tissues

- Low intensity lasers are used therapeutically for their nonthermal effects.
- Visible radiations are remarkably absorbed in the hemoglobin whereas infrared light is strongly absorbed by water.
- Absorption results in the transformation of energy in the body tissues.

Laser Therapy

Interaction of Laser with Body Tissues

- Human body consists of 70% of water and 30% of organic material.
- Organic material which absorbs visible light contains chromophores.
- Chromophores are defined as the molecular structures which get excited by the visible spectrum due to its configuration.
- In human body, hemoglobin and melanin contain chromophores and thus absorbs laser energy.

Laser Therapy

Physiological effects & Therapeutic uses

- ✓ Wound healing
- ✓ Tensile strength and scar tissues
- ✓ Musculoskeletal conditions
- ✓ Pain relief
- ✓ Bone and articular cartilage

Physiological Effects and Therapeutic Uses of Laser

Wound healing

- Laser therapy is used for the treatment of wounds.
- It is a complex physiological process which involves chemotactic activity, vascular changes and the release of chemical mediators.
- Radiations particularly from the red spectrum of light are effective for the treatment of chronic ulcers.

Laser Therapy

Physiological effects & Therapeutic uses

- ✓ Wound healing
- ✓ Tensile strength and scar tissues
- ✓ Musculoskeletal conditions
- ✓ Pain relief
- ✓ Bone and articular cartilage

Physiological Effects and Therapeutic Uses of Laser

Wound healing

- Untreated chronic ulcers and trophic ulcers can be effectively treated by laser therapy.
- Laser therapy increases tissue proliferation and thus enhances wound healing caused due to burns, surgical incisions, diabetic ulcers and pressure sores.
- Grid method or scanning method can be used for healing of wounds.

Laser Therapy

Physiological effects & Therapeutic uses

- ✓ Wound healing
- ✓ Tensile strength and scar tissues
- ✓ Musculoskeletal conditions
- ✓ Pain relief
- ✓ Bone and articular cartilage

Physiological Effects and Therapeutic Uses of Laser

Wound healing

- Wound margins are effectively treated by direct contact technique. For this, the laser probe is usually applied at 1 to 2 cm from the edges with dosage of 4 to 10 joules/cm2.
- Wound bed is treated preferably by noncontact method with the dosage from 1 to 5 joules/cm2. Because the protective layer of dermis is absent in this area, the low dosages are usually sufficient .

Laser Therapy

Physiological effects & Therapeutic uses

- ✓ Wound healing
- ✓ Tensile strength and scar tissues
- ✓ Musculoskeletal conditions
- ✓ Pain relief
- ✓ Bone and articular cartilage

Physiological Effects and Therapeutic Uses of Laser

Tensile strength and scar tissue

- Laser-treated wounds have significantly greater tensile strength than the normally healed ones.
- This tensile strength is directly related to the increased levels of collagen.
- Collagen synthesis and thus the tensile strength are fibroblasts mediated functions which are improved significantly by the treatment of laser.

Laser Therapy

Physiological effects & Therapeutic uses

- ✓ Wound healing
- ✓ Tensile strength and scar tissues
- ✓ Musculoskeletal conditions
- ✓ Pain relief
- ✓ Bone and articular cartilage

Physiological Effects and Therapeutic Uses of Laser

Tensile strength and scar tissue

- The wounds exposed to laser therapy have more epithelialization and less exudate formation.
- Hence, they have less scar tissue formation with a better cosmetic appearance.

Laser Therapy

Physiological effects & Therapeutic uses

- ✓ Wound healing
- ✓ Tensile strength and scar tissues
- ✓ Musculoskeletal conditions
- ✓ Pain relief
- ✓ Bone and articular cartilage

Physiological Effects and Therapeutic Uses of Laser

Musculoskeletal conditions

The laser therapy can be used effectively in

- Various overuse tendinitis or bursitis conditions
- Some acute conditions as it enhances the healing process and relieves pain
- Various arthritic conditions

Laser has its effect on prostaglandin synthesis and thus it relieves inflammation.

It is found to be very effective in the healing of the connective tissues.

Laser Therapy

Physiological effects & Therapeutic uses

- ✓ Wound healing
- ✓ Tensile strength and scar tissues
- ✓ Musculoskeletal conditions
- ✓ Pain relief
- ✓ Bone and articular cartilage

Physiological Effects and Therapeutic Uses of Laser

Musculoskeletal conditions

- Laser therapy has bactericidal effects because of increased phagocytosis by leukocytes.
- When used in conjunction with antibiotics, laser therapy is found effective in the treatment of various inflammatory conditions.

Laser Therapy

Physiological effects & Therapeutic uses

- ✓ Wound healing
- ✓ Tensile strength and scar tissues
- ✓ Musculoskeletal conditions
- ✓ Pain relief
- ✓ Bone and articular cartilage

Physiological Effects and Therapeutic Uses of Laser

Pain relief

- Laser therapy is effective in relieving acute pain and chronic pain.
- The laser relieves acute pain by reducing swelling and enhancing the healing process.
- In postoperative conditions, the laser is found effective in the enhancing healing process and thus reducing pain.
- Analgesia is achieved in certain neurogenic conditions.

Laser Therapy

Physiological effects & Therapeutic uses

- ✓ Wound healing
- ✓ Tensile strength and scar tissues
- ✓ Musculoskeletal conditions
- ✓ Pain relief
- ✓ Bone and articular cartilage

Physiological Effects and Therapeutic Uses of Laser

Bone and articular cartilage

- The longer duration of low power laser helps in fracture healing and bone remodulation.
- It helps in chondral proliferation and remodeling of the articular line.
- It is also useful for the treatment of nonunion of fractures.

Dangers and Contraindications
- ✓ Effects on
  - Eyes
  - Cancerous growth
  - Pregnant uterus
  - Infected tissues
- ✓ Hemorrhagic areas or cardiac conditions

Dangers and Contraindications

Effects on eyes

- The main danger of low power laser therapy is a risk of eye damage if the beam is applied directly into the eye.
- To avoid the exposure of eye with a beam of laser, protective goggles should be worn by the patient as well as by the physiotherapist.

Dangers and Contraindications
- ✓ Effects on
  - Eyes
  - Cancerous growth
  - Pregnant uterus
  - Infected tissues
- ✓ Hemorrhagic areas or cardiac conditions

Dangers and Contraindications

Effects on cancerous growth

- The laser should not be applied over the area of cancerous growth.
- Laser acts as a photobiostimulatory agent, its exposure to cancerous tissue can lead to acceleration of its growth and metastasis.

Laser Therapy

Dangers and Contraindications

- ✓ Effects on
  - Eyes
  - Cancerous growth
  - Pregnant uterus
  - Infected tissues
- ✓ Hemorrhagic areas or cardiac conditions

Dangers and Contraindications

Effects on pregnant uterus

- Laser should not be applied directly over the pregnant uterus as it may cause abnormal growth.

Effects on infected tissues

- When treated in contact with the infected tissue, the laser head needs to be cleaned thoroughly or sterilized.

Dangers and Contraindications
- ✓ Effects on
  - Eyes
  - Cancerous growth
  - Pregnant uterus
  - Infected tissues
- ✓ Hemorrhagic areas or cardiac conditions

Dangers and Contraindications

Hemorrhagic areas or cardiac conditions

- Laser can cause vasodilatation and hence, care should be taken while exposing any hemorrhagic area.

- Patients of certain cardiac conditions are avoided the exposure of laser therapy around the cardiac region.

Laser Therapy

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