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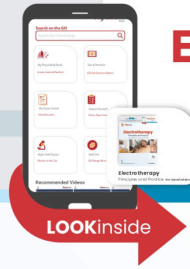

Electrotherapy

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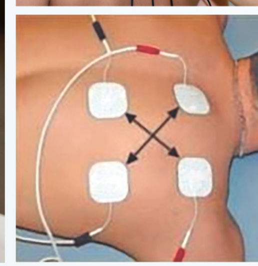

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Electrotherapy

Principles and Practice

As per Physiotherapy Curriculum of All Universities of India and Ministry of Health & Family Welfare

Second Edition

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Foreword

AGK Sinha

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About the Author

Roshan Lal Meena BPT, MPT (Orthopedics), PhD Scholar, is a physical therapist, a teacher, researcher and an author. He completed his graduation in Physiotherapy from National Institute for the Orthopaedically Handicapped, Calcutta, West Bengal in 1998, and Masters degree in Physiotherapy (Orthopedics) from Chaudhary Charan Singh University, Meerut, Uttar Pradesh in 2006. He had joined Pandit Deendayal Upadhayaya National Institute for the Persons with Physical Disabilities, New Delhi in the same year of completion of his BPT. He has been teaching the Bachelor of Physiotherapy students since the time of his joining. He is currently pursuing PhD from Punjabi University, Patiala, Punjab.

He has written a book *Exercise Therapy: Principles and Practice* in 2006 and its subsequent two editions were published in 2014 and 2019. His presentations on "Scope of Physiotherapy and Code of Ethics" and "National Workshop on Development of Syllabus for Innovative Practices and Standards of Physiotherapy" organized by Delhi Council for Physiotherapist and Occupational Therapist are a few of the contributions toward the development of physiotherapy profession. He has also published several papers in national and international journals. Last but not least, he has been given additional responsibilities of Course Coordinator and Nodal Officer, "National Scholarship Portal".

Foreword

Electrotherapy is an integral part of physiotherapy. As a teacher, I have observed that there exists a dearth of evidence-based textbooks in electrotherapy which guide the students and practitioners alike about the doses and parameters of electrotherapeutic agents. This often poses a difficulty to the young physiotherapists in managing the patients effectively as the inappropriate doses and parameters of the physical agents fail to achieve the anticipated effects and outcomes. This has largely contributed to the diminished use of electrotherapy modalities over the years.

In this situation, it is pleasant to observe that Roshan Lal Meena has come up with a book that is primarily intervention oriented and is based on the evidences. The author has described physical agents along with their production, physiological effects, clinical uses, indications, contraindications, and the procedures of application effectively and efficiently. The language of book is lucid and easily comprehendible. The book will prove to be a valuable addition to the existing body of knowledge.

I congratulate the author for this endeavor and wish him all the success.

AGK Sinha
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Preface to the Second Edition

This edition of the book takes it to the next level and forms a valuable addition to the existing body of knowledge. All the chapters of the book have been reviewed by experienced faculties and necessary suggestions and advices have also been incorporated. This edition of the book includes three new chapters—Biophysics, Functional Electrical Stimulation and Biofeedback.

Chapter 1 on **Biophysics** describes the concepts of biophysics, how the different systems of the body, circulatory, nervous, metabolic, musculoskeletal, and cardiorespiratory respond to the various physical agents such as current, light, heat, cold, sound waves and electromagnetic waves. Chapter 13 on **Functional Electrical Stimulation** describes the principles and mechanism of FES action and various parameters. The chapter also explains the uses of FES in post-stroke hemiparetic individuals. Chapter 23 on **Biofeedback** describes biofeedback, its principles, basic instrumentation and settings. The chapter also describes electromyography biofeedback, its indications, contraindications, uses in improving muscle strength and inhibiting muscle tone in patients with musculoskeletal and upper motor neuron lesion.

Although the book is intended mainly for the students of Bachelor of Physiotherapy, I hope it will also be useful for the physiotherapy faculties in imparting the education as well as for managing patients with various ailments and conditions.

Roshan Lal Meena

Preface to the First Edition

The use of electrotherapy continues to have greater importance in patients with various musculoskeletal disorders and injuries. The practice of therapeutic modalities has been remarkably extended to the wide range of musculoskeletal, neurological, cardiovascular and obstetrical and gynecological ailments.

The concept for this book has evolved from a desire to generate and provide a comprehensive text for the students of physical therapy, physical therapists, and is other rehabilitation practitioners. The text is arranged and organized systematically from basics to the advanced and is evidenced-based.

The readers may begin with the first chapter which describes the understanding of pain and functional limitations caused by pain. Each therapeutic modality is described with its various sources of production, physical characteristics, therapeutic uses, adverse effects and applications. The classification of modalities is based on the depth of penetration of heat, frequency of currents and source of energy. The book covers almost all the therapeutic modalities practiced world wide by the physical therapists.

It is written in simple and clear form with images and diagrams to give the reader a more realistic representation of the modalities. I hope the readers will find the text to be adequate to formulate and design appropriate parameters of the therapeutic modalities for various musculoskeletal disorders, neurological disorders and sports injuries.

Roshan Lal Meena

Acknowledgments

First of all, I would like to express my special gratitude to all my students, colleagues, seniors and head of Physiotherapy department for their excellent support and guidance.

Secondly, I would like to thank my parents, my wife and children for helping me in completing the second edition of this book.

Finally, my special thanks are due to Ms. Annu Raina and Dr. Divya Gupta and associates for their valuable support, suggestions and advices that have helped me in refining the text and making it more comprehensive.

I extend my special thanks to **Mr Satish Kumar Jain** (Chairman) and **Mr Varun Jain** (Managing Director), M/s CBS Publishers and Distributors Pvt Ltd for their wholehearted support in the publication of this book. I have no words to describe the role, efforts, inputs and initiatives undertaken by **Mr Bhupesh Aarora** [Sr Vice President – Publishing & Marketing (Health Sciences Division)] for helping and motivating me.

My special thanks are due to the scientific editorial board of the CBS Physiobrid series, especially Dr Harshita Sharma, Dr Divya Gupta (PT) and Dr Surbhi Jain (PT) (Content Strategists cum Quality Check), and some senior faculties for their tireless efforts to provide valuable inputs throughout the project.

Last but not least, I sincerely thank the entire CBS team for bringing out the book with utmost care and attractive presentation. I would like to thank Ms Nitasha Arora (Publishing Head and Content Strategist – Medical and Nursing), Ms Daljeet Kaur (Assistant Publishing Manager), Ms Annu Raina (Senior Manager – Publishing & Marketing), Dr Anju Dhir (Product Manager cum Commissioning Editor – Medical) for their support. I would also extend my thanks to Mr Shivendu Bhushan Pandey (Sr Manager and Team Lead), Mr Ashutosh Pathak (Sr Proofreader cum Team Coordinator) and all the production team members for devoting laborious hours in designing and typesetting the book.

Special Features of the Book

LEARNING OBJECTIVES

On completion of the chapter, the student will be able to:

- Explain the mechanism of the production of heat in the tissues by the specific range of microwaves.
- Describe the production of microwaves, their behaviors in the tissues and therapeutic effects along with indications and contraindications.

Learning Objectives in the beginning of every Chapter help readers understand the purpose of the chapter.

CHAPTER OUTLINE

- Introduction
- Production
- Physical Characteristics
- Physiological Effects
- Clinical Uses
- 2450 MHz MWD versus 915 MHz MWD
- Indications
- Contraindications
- Application Procedure

Chapter Outline gives a glimpse of the content covered in the chapter.

KEY TERMS

Antenna: It is a piece of wire mounted in form of a metal reflector which emits the microwaves in one direction.

Circular director: It produces 100% or maximum energy beneath the periphery of the director.

Coaxial cable: The cable of wire which connects the director to the magnetron.

Director: The applicator of microwave diathermy which is connected to the magnetron through the coaxial cable that consists of an antenna and reflector.

Key Terms are added in each chapter to help the readers understand difficult scientific terms in easy language.

Numerous **Tables** have been used in the chapters to facilitate learning in a quick way.

TABLE 3.1: MWD with various frequencies and depth of penetration

Frequency	Wavelength	Depth of penetration
2450 MHz	12.24 cm	1.85 cm
915 MHz	32.8 cm	5 cm
433.9 MHz	69.1 cm	Above 5 cm (still under trial)

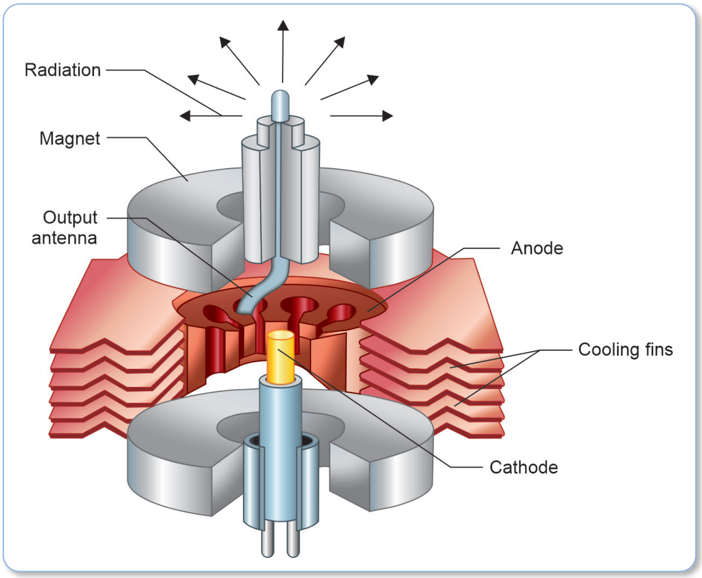

Figure 3.2: Magnetron

The book is well illustrated with relevant colorful **Figures**, etc.

Must Know boxes give an overview of important facts and terms of the concerned topic.

Must Know

Microwave radiation is defined as waves having a frequency of 300–3000 MHz in the electromagnetic spectrum between radiofrequency and shortwave diathermy. There are three types of MW diathermies, 2450 MHz (12.24 cm wavelength), 915 MHz (32.8 cm wavelength) and 434 MHz (69.1 cm wavelength) used in the physical therapy practice. The higher is the frequency, the lower the depth of penetration, hence 915 MHz and 434 MHz microwave diathermies produce heating effect up to 5 cm tissue depth directly, whereas, 2450 MHz MWD reaches up to 1.85 cm depth directly.

Practical Tip

In physiotherapy practice, the significant elongation of the short connective tissues can be achieved if stretching is performed along with hyperthermia of the tissues at the therapeutic range between 41°C and 45°C.

Practical Tips have been extensively covered from applied perspective.

Recent Update

434 MHz MWD is also introduced and being tried in some countries for its deep heating thermal effects.

Any advancements that have taken place in recent times relevant to study and practice are covered as **Recent Update**.

Summary

- Microwave radiation is defined as waves having a frequency of 300–3000 MHz in the electromagnetic spectrum between radiofrequency and shortwave diathermy. There are three types of MW diathermies, 2450 MHz (12.24 cm wavelength), 915 MHz (32.8 cm wavelength) and 434 MHz (69.1 cm wavelength) used in the physical therapy practice. The higher the frequency, the lower the depth of penetration, hence 915 MHz and 434 MHz microwave diathermies produce heating effect up to 5 cm tissue depth directly, whereas, 2450 MHz MWD reaches up to 1.85 cm depth directly.
- The microwave radiation is radiated as a beam from an antenna and is absorbed by water-rich tissues 7000 times effectively than shortwave radio frequency energy. The tissues of high-water contents, like muscles and fluid-filled organs such as eyes, and joints are heated preferentially.

Important takeaway points of respective chapters have been highlighted under **Summary** boxes.

References

1. A. Giombini, V. Giovannini, A. Di Cesare, P. Pacetti, Noriko Ichinoseki-Sekinel, M. Shiraishi, Hisashi Naitol and Nicola Maffulli. Hyperthermia induced by microwave diathermy in the macagement of muscle and tendon injuries. Department of Trauma, and Prthopedic Surgery, Keele University School of Medicine, Stoke on Trent, StaffS, UK, June 2008.

Giving extra edge to the study **References** have been included at the end of every Chapter.

ASSESS YOURSELF

Long Answer Questions

1. Explain in detail the production of microwave diathermy. Write a note on magnetron.
2. Explain in detail the characteristics of microwaves used in the physiotherapy practice. What are the optical laws of radiation?

Short Answer Questions

1. Which device is used to produce the microwaves?
2. What is the magnetron?

At the end of each chapter, **Assess Yourself** section is given which contains frequently asked questions in exams to help students attain mastery over the subject.

Contents

UNIT I BIOPHYSICS

UNIT II HEATING AGENTS

UNIT V MECHANICAL AGENTS

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UNIT VIII ELECTRODIAGNOSIS

Unit

VI

Light: A Therapeutic Healing Agent

UNIT OUTLINE

Light Amplification by Stimulated Emission of Radiation

18

LEARNING OBJECTIVES

On completion of the chapter, the student will be able to:

- Obtain sound knowledge and deep understanding of laser light.
- Describe the production, physical characteristics, classification, types, physiological effects, clinical uses, indications, contraindications and procedure of application of laser.
- Understand how laser is effective in healing and how it can be applied to the patients with various ailments.

CHAPTER OUTLINE

- Introduction
- Laser Classification
- Laser Production
- Physical Characteristics
- Laser Types
- Physiological Effects
- Clinical Uses
- Application Parameters
- Indications
- Precautions
- Contraindications
- Application Procedure

KEY TERMS

Coherence: All the photons of light emitted from individual gas molecules remain in phase with each other and travel in the same direction. The individual light waves are located in step with another.

Collimated beam: Collimation beam refers to the minimal divergence of the photons in a laser beam.

High power laser: The laser with the power of >500 mW is called high power laser. These types of lasers pose hazards to eyes and skin and cannot be operated without goggles. The common use of class IV laser is in the surgical interventions.

LASER: It is an acronym for light amplification by stimulated emission of radiation.

Lasing cavity: It is the chamber or cavity that contains gases such as CO_2 or helium neon used to produce Laser. Laser cavity contains two mirrors opposite to each other. The semipermeable mirror allows the photons to pass partially whereas reflecting mirror does not allow the photons to pass, in fact, it further amplifies the light by reflecting the photons.

Low level laser: The laser with power output of less than 500 mW is called low level laser. Low level lasers are used in the physiotherapy practice across the globe for their healing effects.

Monochromatic: Monochromatic is a light of single frequency, single wavelength, and single color. For example, He-Ne produces a red light. Because of its wavelength specificity, laser light is characteristically pure.

Contd...

Population inversion: It is raising of the atoms, ions, or molecules of the medium from their ground state (E_1) to one of the several tiers of upper energy state (E_2).

Spontaneous emission: The electrons at the upper tier state (E_2) are inherently unstable and fall spontaneously within a short period of time to lower energy levels and release extra energy as photon of light.

Stimulated emission: The photon of appropriate energy strikes an atom while it is maintained in an excited state, the atom is immediately stimulated to emit its excess energy and make its transition to the ground state.

INTRODUCTION

The term LASER is an acronym for light amplification by stimulated emission of radiation.[1] Laser is a form of light and the healing properties of the light have been described since ancient Roman times.[2] The laser light differs from the ordinary light emitted by other sources in terms of beam, consistency, coherence and wavelength. The laser light is the form of focused, parallel monochromatic beam with the high intensity.

A laser is generally used as a source or generator of radiation.[3] Radiation is the process by which energy is propagated through space. The direction of propagation of radiant energy, usually, remains straight. It is absorbed by the medium through which it travels. The velocity of the radiant energy remains equal in a vacuum, but may vary with different media. This radiating energy is collectively known as electromagnetic radiation. A laser light when enters into the tissues (medium), is either absorbed or reflected at the superficial structures; therefore, its velocity does not remain equal in the tissues.

Laser technology is rapidly advancing and its application to medical fraternity is constantly growing. Initially ophthalmic surgeons were the first to use the first ruby laser successfully for the treatment of detached retina in humans.[4] The major use of the laser in medicine is based on the photothermal and photoablative interactions of laser with tissues such as cut, weld and even to destroy tissues.

A low power laser was introduced in the United States with the claim that the device could help in reducing pain, spasm, and inflammation and prompt healing.[5] The use of low levels of visible or near-infrared light for reducing pain, inflammation, edema, and promoting healing of wounds, and nerves has been known for almost forty years since the invention of lasers.

Must Know

Laser used in the physiotherapy practice produces a **monochromatic** (single wavelength), **collimated** (directional), and **coherent** (in phase) non-invasive light and is used to enhance the functions of connective tissue cells, accelerate connective tissue repair and act as an anti-inflammatory agent.

LASER CLASSIFICATION

The classification of laser into five classes is based on energy, power, and wavelength.

- **Class I:** The laser with power of <0.5 mW in the visible and invisible range has no therapeutic effects. It is primarily used for the blackboard pointers, barcoding reading at shopping centers, CD players and laser printers. These lasers typically are enclosed and pose no danger to use.
- **Class II:** The laser with power output up to 1 mW has limited effects. These types of lasers are safe for momentary viewing. The laser provokes a blink reflex.

- **Class III:** Class III is divided further into class IIIA and IIIB.
  - **Class IIIA:** The laser with power output of <5 mW is placed in this class. These types of lasers are commonly used for laser pointers. Eyes can be damaged if exposed to type IIIA for prolonged period of time. Class IIIA lasers such as He-Ne lasers (not exceeding 5 milliwatt) energy does not produce injury with momentary viewing.
  - **Class IIIB:** The laser with power output of 5 mW to 500 mW has been sub classified into IIIB. These types of lasers are called cold laser, low power laser, low intensity laser and soft laser. Type IIIB lasers produce significant therapeutic effects in the tissues. The food and drug administration (FDA), USA allowed class IIIB laser to be used in the physiotherapy clinics; however, certification is needed before applying to the patient.

  The class III laser is a form of electromagnetic energy with a wavelength of 600 to 1000 nm, falls within the visible or infrared section of the electromagnetic spectrum.

Practical Tip

Class III laser has adverse effects on naked eyes, it is, therefore, necessary for the clinician and the patient to put on protective goggles, during application of the laser.

  He-Ne (Helium-Neon) and GaAs (gallium arsenide) with wavelength of 632.8 nm and 850 nm respectively produce class III (low power) lasers. Class IIIB lasers, above 5 mW energy (but not exceeding 500 mW), may cause injury with direct viewing of the beam or specular reflection; however, do not cause danger to the skin.

- **Class IV:** The lasers with the power of >500 mW are categorized into class IV. These types of lasers pose hazards to eyes and skin and cannot be operated without goggles. The common use of class IV is in the surgical interventions. However, it is also used therapeutically for pain reduction.

LASER PRODUCTION

Laser is produced in the lasing cavity. Lasing cavity is also known as optical cavity that comprises lasing material, pump source, optical mirrors and output coupler (Fig. 18.1).

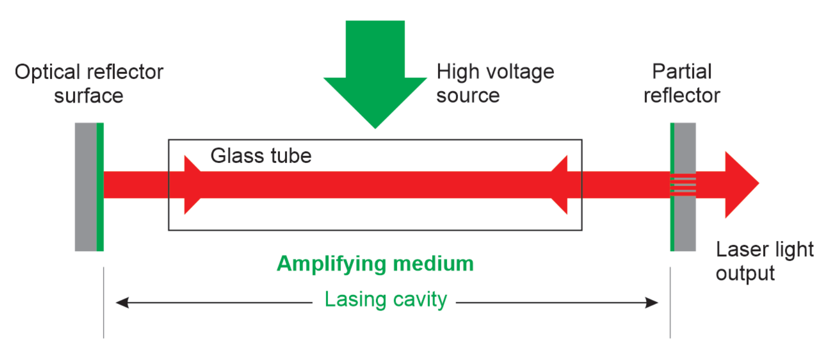


Figure 18.1: Lasing cavity and its components

Lasing material placed in the lasing cavity may either be gas, liquid, or solid. The medium is also known as gain medium. The energy required for excitation of the medium is often supplied by electric current, or an intense light source, such as a flash lamp or an excitable laser. Chemical and mechanical sources can also be used for exciting the gain medium.

There are two optical mirrors on each side of the lasing cavity, one fully reflected and other partially reflected. These mirrors get the photons reflected back and forth to amplify the light. Partially reflected mirror allows photons to pass to the fiber optic cable through the output coupler. The following steps happen in the production of laser light.

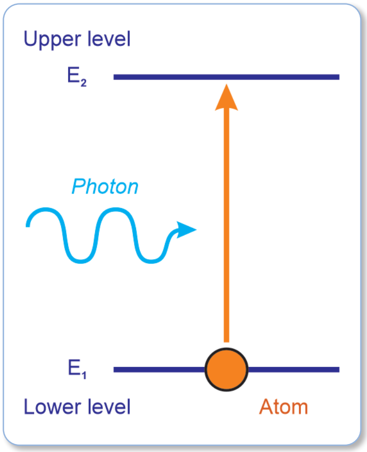


Figure 18.2: Population Inversion

Population Inversion

A high intensity flash lamp is used to raise the atoms, ions, or molecules of the medium from their ground state (E_1) to one of several tiers of upper energy state (E_2)[6]. There comes a point where the number of excited atoms in the upper energy state (E_2) are more than the atoms in the lower energy level (E_1). This condition is known as population inversion and it is the precondition for laser light production (Fig. 18.2).

Spontaneous Emission

In the three energy levels, the atoms are first excited to a short-lived high energy state that spontaneously drop to a somewhat lower energy state with an unusually long lifetime, called a metastable state (Fig. 18.3).

Therefore, once, the electrons shift to their high energy orbits, they are inherently unstable. The atoms fall spontaneously within a short period of time to their lower energy levels and in so doing release their extra energy as photon of light.[4] It is the quantum of energy representing the difference between the ground state (E_1) and excited state (E_2). It is called spontaneous emission. The photon emitted from the atom while decaying from upper energy level to the lower energy level has a random direction and random phase (Fig. 18.4).

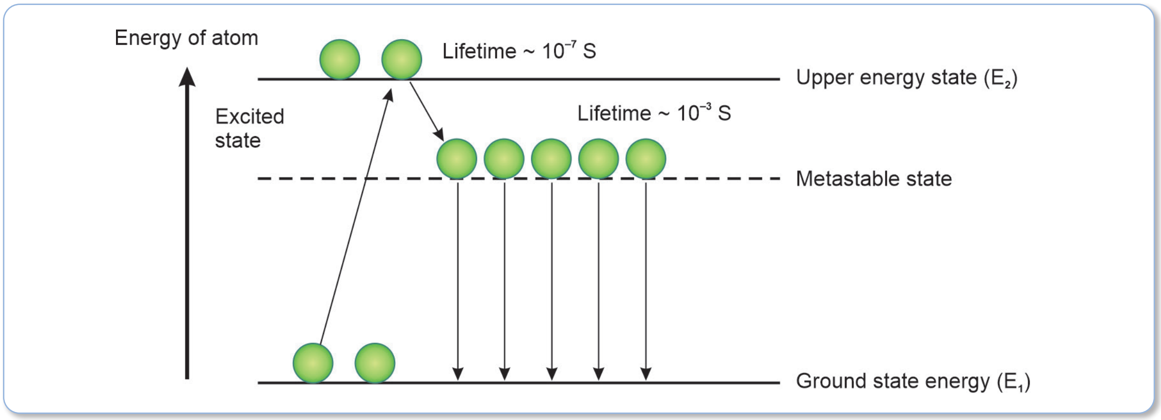


Figure 18.3: Metastable state. The excited atom falls spontaneously from the higher tier of energy into the metastable state

Stimulated Emission

If an unstable excited atom is allowed to reach to its ground state, this process will prevent the energy transfer level necessary for laser production. If however, a photon of appropriate energy strikes an atom while it is maintained in an excited state, the atom is immediately stimulated to emit its excess energy and make its transition to the ground state (Fig. 18.5). This process is called stimulated emission.[2]

Therefore, to produce a laser light, a photon collides with the excited atom and produces two identical photons. These two identical photons collide with another excited atom either at the upper higher energy tier or at the metastable state and produce four identical photons, then eight and so on. This process of producing identical photons is called stimulated emission (Fig. 18.6).

The photons of excited state are aligned in a lasing chamber where they hit the semipermeable silver resonating mirror, and then reflect to the reflecting mirror. The reflection of the photons between two mirrors

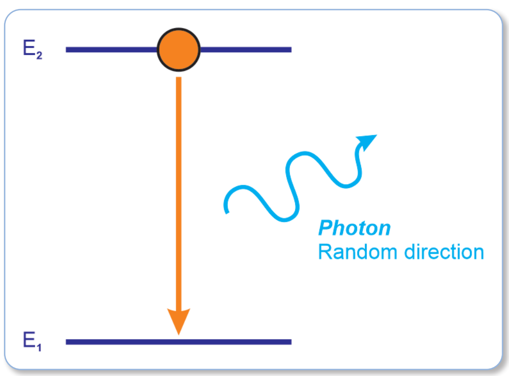


Figure 18.4: Spontaneous emission. The excited atom remains at the upper energy level for a short period of time and then falls spontaneously and produces a photon. The emitted photon has a random direction.

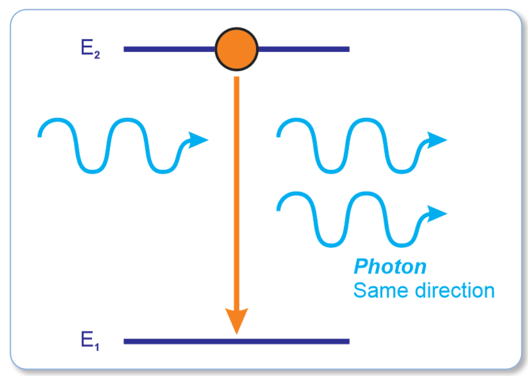


Figure 18.5: Stimulated emission. The excited atom falls spontaneously and releases energy in the form of photon. The photon of an appropriate energy collides with the other excited atoms either at the higher tier level state or at the metastable state and produces two identical photons. The photons remain in a phase and have same direction.

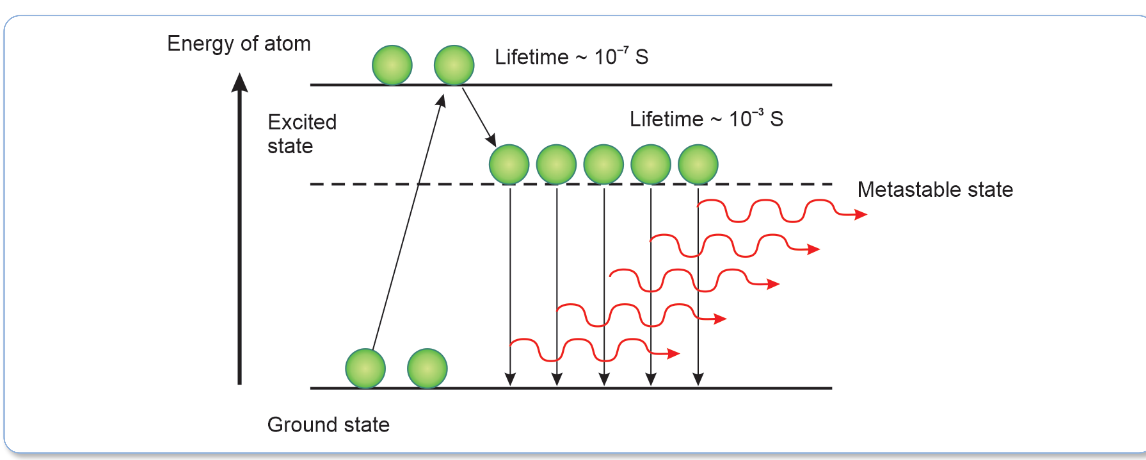


Figure 18.6: Stimulated emission. Production of identical photons of same phase and direction.

back and forth in the lasing chamber through the medium further amplifies the light. This produces intense photon resonance. The emitted photons travel in uniform direction and phase.

The semipermeable reflecting mirror (surface) also known as output coupler allows photons to eject from the chamber into the fiber optic cable. The fiber optic cable is a threadlike filament composed of glass that guides the stimulated photons by directing them to the treatment surface.

When the contact between the laser and skin is established, the laser can be transmitted, reflected, absorbed or dispersed. The absorption and depth of penetration depend upon the tissue contents and laser wavelength.

PHYSICAL CHARACTERISTICS

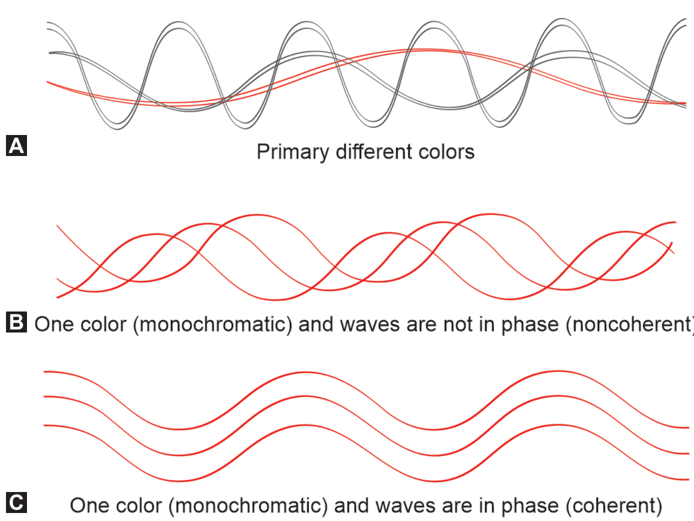
There are three properties of laser that distinguishes it from incandescent and fluorescent light source—1. Coherence, 2. Monochromaticity, and 3. Collimation.

1. Coherence

All of the photons of light emitted from individual gas molecules remain in phase with each other and travel in the same direction. The individual light waves are located in step with another.

Temporal coherence: When all the waves are in phase.

Spatial coherence: When the waves travel in the same direction. Spatial coherence allows the light to be directed through a focusing lens and directly propagated to targeted tissues because of its directional stability. The spatial and temporal coherence minimize divergence and focus the energy so that it is concentrated on one area. To achieve temporal and spatial coherence, the photons are aligned in a reflecting chamber. The photons are then reflected back and forth between mirrors to achieve amplification before being ejected through a fiber optic cable or a diode to reach the area to be treated (Figs 18.7A to C).



Figures 18.7A to C: **A** and **B.** Noncoherent light; **C.** Coherent light in which all the photons are in phase and travel in the same direction

2. Monochromaticity

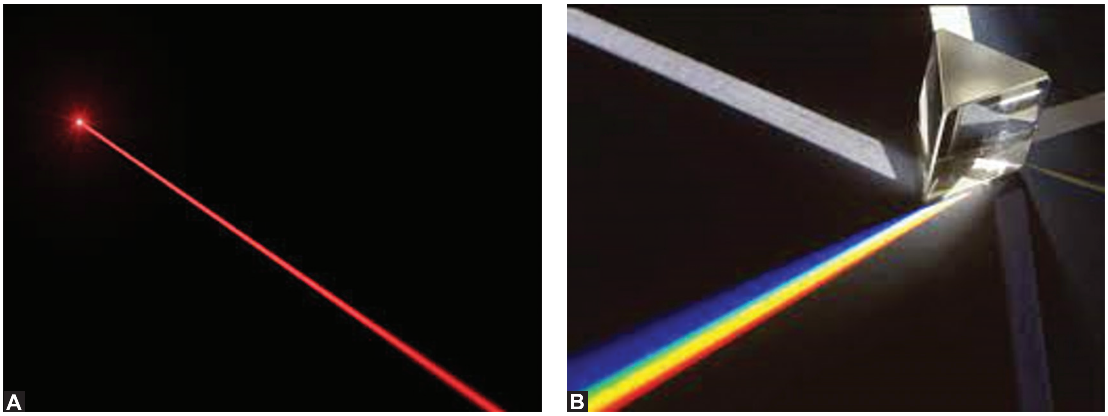
Monochromatic beam is a light of single frequency, single wavelength, and single color. For example, He-Ne produces a red light. Because of its wavelength specificity, laser light is characteristically pure (Figs 18.8A and B).

3. Collimation

Collimation refers to the minimal divergence of the photons in a laser beam (Fig. 18.9) making the beam focused.

Wavelength

Lasers with varying wavelength (Fig. 18.10) ranging from 632 nm to 904 nm are used in the management of musculoskeletal disorders. Treatment by such range of wavelength of lasers is called low level laser therapy (LLLT).



Figures 18.8A and B: **A.** Monochromatic single color; **B.** Nonmonochromatic light with multiple color

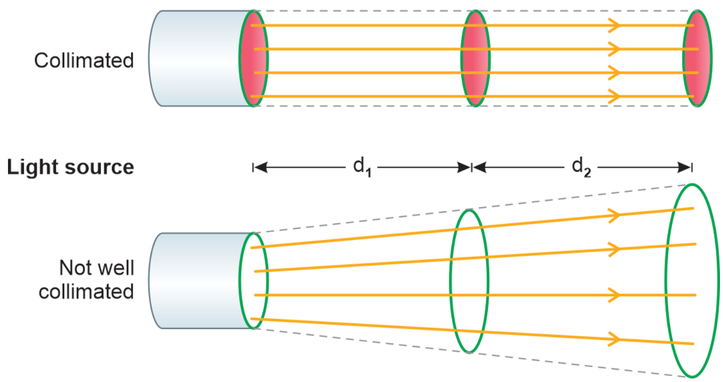


Figure 18.9: Noncollimated and collimated beam

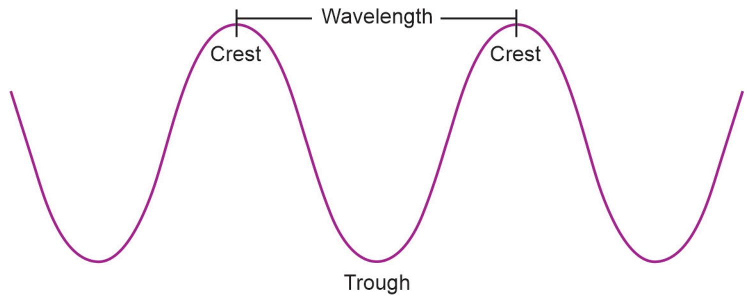


Figure 18.10: Wavelength is the distance between identical points or adjacent crests in the cycles of a waveform signal propagated in space or along a wire, specified in nanometer. Wavelength is inversely related to the frequency, the higher the frequency of the signals, the shorter the wavelength.

This range of wavelength has the ability to penetrate the skin and soft tissues with good effect on pain, inflammation and tissue repair. The lasers with longer wavelength will penetrate deeper than the lasers with shorter wavelength. He-Ne, Ruby, and gallium arsenide consists of 632.8 nm, 694.3 nm and 850 nm respectively. Gallium arsenide has deeper penetrating effects than the He-Ne and Ruby laser due to higher wavelength.

The wavelength between 600 nm and 700 nm produces visible red light. Near infrared light generally refers to light within the wavelength ranging from 800 nm to 2500 nm. Red light laser (600 nm to 700 nm) is commonly used in the physiotherapy practice for treating various musculoskeletal disorders, however, near infrared laser closer to the red light is also used in the physiotherapy and rehabilitation. The far infrared is closer to the microwave region of the electromagnetic spectrum.

Transmission

The human body tissues are nonhomogenous with significant density difference in the interfaces. The size, shape, and density of these structures, their refractive index, and the polarization state of the incident light predetermine the propagation characteristics of light in tissues. The transmission of the laser light within the tissues depends upon the scattering and absorption by the cells, cell organelles and different fiber and tubular/lamellar structures.

Penetration

The thickness of the dermis, the presence or absence of muscular, adipose, or osseous tissues are all important when considering the penetration of tissues by laser radiation. The depth of penetration of He-Ne laser directly occurs at approximately 3 mm of soft tissue thickness and that indirect penetration can occur up to 1 cm. Since the light of the He-Ne is of red color, it will penetrate deeper into pale tissues than into red tissues (i.e., oral cavity). This finding should mean that the laser therapy does not have really direct effects on the deeper tissues. However, the effects can be mediated by many different pathways.[7]

Practical Tip

The He-Ne laser is, therefore, primarily used for direct skin stimulation and for the stimulation of acupuncture points that have a superficial location.

The depth of penetration of the laser light in the tissues is increased as the wavelength of the laser increases up to mid-infrared, where water that is present in the tissues absorbs most of the energy of laser light.[8]

Must Know

The depth of penetration of laser light decreases with more scattering of light. The shorter the wavelength, the greater the scattering of light in the superficial tissues. Intensity also determines the scattering of light. Higher the intensity, less the scattering and greater would be the penetration. Hence, scattering and absorption in the tissues eventually decay the transmission of laser light to the deeper tissues.

The pulse infrared laser appears to penetrate to the depths of 1.5 cm in soft tissues. It is, therefore, less absorbed in the dermis and more absorbed in the deeper and dense tissues, such as ligaments, tendons, and muscle and may be in the periosteum. Infrared laser irradiation as a power of 10 mW will result in a penetration depth of 18 mm in the bone axis direction and 6 mm in the corticomedullar direction.[9, 10] (Table 18.1).

Absorption

A prerequisite for absorption is that the wavelength of the irradiated light is suited to the absorbing material (Fig. 18.11). The resonance of human tissue is such that it absorbs the light of laser quite well. This is based on the theory that human tissue cells oscillate at a frequency that is very similar to that of laser light.[11]

TABLE 18.1: Laser and parameters

Laser	Wavelength	Gain medium	Mode	Depth of penetration
He-Ne	632.8 nm	Gas	Continuous	3 mm direct and up to 1 cm indirectly
Ruby	694.3 nm	Solid/Ruby Crystal	Pulse	4 mm direct and up to 1 cm indirectly
Gallium arsenide	850 nm	Solid/Junction diode	Pulse	4–5 mm
Infrared	1064 nm	Solid state laser	Pulse	1.5 cm

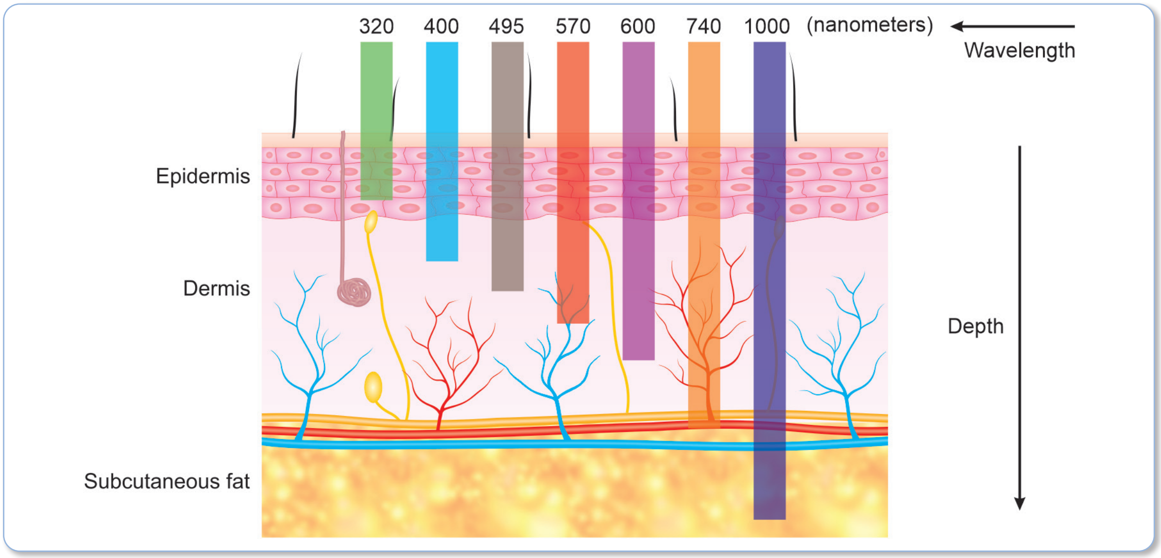


Figure 18.11: Depth of penetration of laser with various wavelengths

Human skin exhibits specific properties that determine the penetration and absorption of laser light by skin cells. The photons of specific wavelength emitted by the laser are absorbed by the chromophores, an endogenous compound. Water, melanin, and hemoglobin are three primary endogenous cutaneous chromophores.[12] The major portion of the energy approximately 50% of ruby laser is lost in the first 1 mm of the skin and reduces further into the deeper but at a much slower rate.[13]

LASER TYPES

There are several types of lasers, few of them used in the physiotherapy practice are mentioned as follows.

Ruby Laser

- **Medium:** Synthetic Red Ruby Crystal
- **Pump source:** Flash light
- **Mode:** Pulse
- **State:** Solid
- **Wavelength:** 694.3 nm
- **Color:** Deep Red
- **Depth of penetration:** 4 mm (direct).

The first working laser was ruby laser made by Theodore H. "Ted" Maiman at Hughes Research Laboratories on May 16, 1960.[14] Ruby laser is a solid state laser that uses a synthetic ruby crystal as its gain medium. This type of laser produces pulses of coherent visible lights at a wavelength of 694.3 nm, with a deep red color. Typical ruby laser pulse lengths are of the order of a millisecond. Ruby laser most often consists of a synthetic rod that is energized through optical pumping, typically by a xenon flashtube. Electrical stimulation to the flashtube causes the excitation of the ruby molecules that raise the electrons to a higher energy level. The electrons stay at the higher level for a short time, before falling to the metastable level where they stay for longer time.[15] Population inversion occurs as the electrons increase in the upper tier of energy level and metastable level than the ground level. This whole process occurs in the lasing chamber which contains total reflection and partial reflection mirrors. The semipermeable (partial) mirror allows some of the photons to emit from the chamber into the fiber optic cable in the form of red light of 694.3 nm wavelength.

Helium Neon Laser

- **Medium:** Atoms of Helium and Neon Gas
- **Pump source:** Flash Gun (Electric)
- **Mode:** Continuous
- **State:** Gas
- **Wavelength:** 632.8 nm
- **Color:** Deep Red
- **Depth of penetration:** 3 mm direct and up to 1 cm indirectly

Helium-Neon (He-Ne) laser is produced by a tube containing atoms of helium and neon. The helium gas atoms are elevated or excited from the ground state by application of electrical stimulation called a flash gun. The excited level of helium atom very closely approximate ground level of the neon atom. When excited helium atom collides with a ground state neon atom, the energy produced is transferred to the neon atom, and the helium returns to the ground state. The concentration of the photons in the excited level is more than the ground level that leads to population inversion. The photons reflect to and fro between mirrors along the tube. The semipermeable mirror allows photons from the tube into the fiber optic cable in the form of red light of 632.8 nm wavelength.

Gallium Arsenide Laser

- **Medium:** Junction diode with thin coating of zinc
- **Pump source:** Diode
- **Mode:** Pulse
- **State:** Solid
- **Wavelength:** 850 nm
- **Color:** Red
- **Depth of penetration:** 4–5 mm

Gallium arsenide laser was the first semiconductor laser used in 1962. This laser has the wavelength of 850 nm. This laser is housed in a diode. Diode is an electrical component that allows electrical current to pass in one direction through the device offering high level of electrical resistance in the reverse direction. A junction diode is formed by depositing a thin coating of zinc in the device that allows electric current to flow more readily in the direction from zinc to Gallium Arsenide. The laser reaction occurs in this junction region and energy is delivered in the pulsed mode. The indirect depth of penetration of this type of laser is 4–5 mm.

PHYSIOLOGICAL EFFECTS

The investigation into the biologic and physical effects of cold laser radiation is still in its early stages.[2] The effects of laser on biological tissues are directly related to the wavelength of the beam, the depth to which it penetrates, and the dosage (energy density, intensity and duration of the treatment).[5] The human skin absorbs as much as 99% of the radiation; dark skin absorbs more light.[16]

The biostimulation effects of cold lasers are essentially nonthermal and are produced mainly by photochemical means. Photons in the form of light emitted from the output coupler of resonating cavity are carried by the fiber optical cable to the applicator where they are finally transmitted into the tissues.

To produce physiological changes in the tissues, the photons must be absorbed by electronic absorption bands belonging to a photon acceptor or chromophore. A chromophore is a light absorbing part of a molecule that gives color to the molecule or part of it and that can be stimulated by light energy to undergo biochemical reactions. Cytochrome-c oxidase is the compound in the cell which is colored by the chromophore and is considered to be primary photo-acceptor for the red-near-infrared laser. The studies have shown that the chromophore receives the laser light and causes significant biochemical changes at the cellular and subcellular levels, including ATP and RNA production.

Must Know

Some of the physiological effects attributed to the low power laser include:
- Stimulate mitochondria
- Dissociate nitric oxide from cytochrome-c oxidase
- Increase reactive oxygen species and decrease reactive nitrogen species
- Enhance cell proliferation of fibroblast, keratinocytes, endothelial cells and lymphocytes
- Increase growth factors
- Enhance neovascularization
- Promote angiogenesis
- Increase collagen synthesis
- Increase metabolism and transport action potential in neurons

Effects on Cell

Mitochondria are the cellular power plants in our cells as they convert food molecules and oxygen into energy by oxidative phosphorylation. The primary function of mitochondria is to produce ATP which is used as the energy source for all other cellular reactions. Nitric oxide binds with the cytochrome-c oxidase following injury and inhibits the respiration of the cell. This results in displacement of oxygen especially in the injured hypoxic cells. It is believed that laser light can photo-dissociate nitric oxide from cytochrome-c oxidase and reverse the mitochondrial inhibition of respiration due to excessive nitric oxide binding. Increased cytochrome oxidase production promotes ATP synthesis, and enhances electron transfer. This effect may be partially mediated by cellular or mitochondrial calcium uptake. Laser light can increase the production of ATP by up to 70%.

Effects on Peripheral Nerves

The peripheral nerve endings of nociceptors, consisting of the thin myelinated A delta and unmyelinated, slow-conducting C fibers, lie within the epidermis. In neurons, adenosine triphosphate (ATP) is synthesized by mitochondria in the dorsal root ganglion. The cell bodies of neurons lie within the dorsal nerve root ganglion, but the elongated cytoplasm (axon) of the neurons extends from the cell body to the bare nerve endings in the surface of the skin. This arrangement of neural network is within the reach of laser light. There is a direct effect of laser initially at the level of the epidermal neural network, but the effect is also seen indirectly on the subcutaneous tissues, sympathetic ganglia, and the neuromuscular junction within the muscles and nerve trunks.

Laser affects the neurons in two ways. Low intensity laser stimulates mitochondria and raises mitochondrial membrane potential. It is also believed that laser increases metabolism and transport of action potentials in neurons rather than decrease it. On the other hand, if higher intensity laser is used, it can cause opposite effects such as inhibit mitochondrial metabolism in C fibers and A-delta fibers that eventually induces a nerve blockade. Hence, low doses of laser are more effective than much higher doses.

Vasodilatation

The process of laser induced vasodilatation was first described by RF Furchgott in 1968.[17] There is induction of nitric oxide following application of low level laser therapy. The induction of nitric oxide causes increase in local blood circulation that results in vasodilatation,[18] particularly of the microcirculation.[19] Laser-induced vasodilatation can accelerate the availability of oxygen and other nutrients, and helps in removing the waste products from the irradiated area.

Collagen Synthesis

Laser light has been found effective in facilitating collagen synthesis, keratinocyte cell motility, growth factor release and in transforming fibroblasts to myofibroblasts.[20] It also enhances neovascularization, promotes angiogenesis and increases collagen synthesis to aid in the healing of acute and chronic wounds.[21, 22]

CLINICAL USES

The low levels of visible or near-infrared (NIR) light are used for reducing pain, inflammation and edema, and for promoting wound healing, in deeper tissues and nerves, and preventing tissue damage. The uses have been known for almost forty years since the invention of lasers.

In 1967, a few years after the first working laser was invented, Endre Mester wanted to test if laser radiation might cause cancer in mice.[23] He shaved the dorsal hair, divided them into two groups and gave a laser treatment with a low powered ruby laser (694.3 nm) to one group. They did not get cancer, and to his surprise, the hair on the treated group grew back more quickly than the untreated group. This was the first demonstration of "laser biostimulation." Since then, medical treatment with coherent-light sources (lasers) or noncoherent light (light-emitting diodes, LEDs) has passed through its childhood and adolescence.[24] The following common conditions are effectively managed with the low level laser therapy.

Wound Healing

Low level laser therapy has been promoted for its beneficial effects on tissue healing and pain relief. Some of the studies found direct effect of laser on wound contraction. Low level laser effectively facilitates wound contraction of partial wound and chronic open wound. The laser irradiation on wounds forms granulation tissue up to 25% more than the nonirradiated wounds with enhanced epithelialization and increased phagocytosis.[25–30] Laser irradiation also activates the vessels adjacent to the wound and increases the phagocytic capacity of macrophages, accelerating their activity to clear the way for the advancing vessels, and loosens the fibrin network of the clot.[31] These studies suggest that the low level laser therapy has the stimulating effect on regenerating epithelium.

Practical Tip

Red-infrared band was found more effective in healing the diabetic foot ulcer than the lower wavelength lasers. Red light mediated photo bio-modulation was considered to be the best treatment strategy for the treatment of diabetic foot ulcers.[32]

Inflammation, Edema and Pain

Following injury, many inflammatory agents are generated at the site of wound in response to phagocytic processes and other irritants. Among these are highly reactive superoxide radicals. These combine with local arachidonic acids to produce prostaglandin-E. Prostaglandin-E is a fatty acid that causes the breakdown of ATP to cyclic AMP and induces changes in nociceptor membrane potentials.[33] This change increases the sensitivity threshold of the nociceptor and thus leads to an increase in its firing rate.[9] In addition to be involved in pain production, prostaglandins also cause increased vasodilatation and further propagate the inflammatory process. A study of Helium-Neon laser effect upon mouse skin found that successive daily Helium-Neon exposure resulted in a significant increase in superoxide dismutase activity.[34] Superoxide dismutase inhibits prostaglandin formation. Low level laser therapy is not only effective as an anti-inflammatory agent but is also involved in the reduction of pain and edema.

Collagen Metabolism

Low level laser therapy can enhance neovascularization, promote angiogenesis and increase collagen synthesis to aid in the healing of acute and chronic wounds. Laser irradiation to the fibroblast, produces mitochondrial and rough endoplasmic reticulum hypertrophy with enlarged cisternae. Numerous microfibrils are found, especially close to the Golgi apparatus following exposure to the laser. Red laser has been shown to promote an increase in collagen synthesis and mRNA production and to induce more than threefold increase in procollagen production.[35]

Subacromial Impingement Syndrome and Supraspinatus Tendinitis

Shoulder pain is one of the common musculoskeletal disorders and can affect the general population up to 25%,[36] hence, it remains a major concern in the rehabilitation. There are numerous causes of shoulder pain, however, subacromial impingement syndrome (SAIS) is one of the most frequent causes of the shoulder joint pain.[37] There is an impingement of subacromial bursa, tendon of supraspinatus and long head of biceps between the head of humerus and acromial arch during the overhead activities. The syndrome is associated with the repetitive overhead activities such as tennis, baseball, throwing, cricket bowling and swimming. The subacromial bursitis pain leads to decreased muscle strength and range of motion (ROM) of the shoulder which adversely affect the patient's quality of life.[38] The SAIS causes edema, inflammation and can become chronic if adequate treatment is not administered.

The conservative treatment approaches such as analgesic and nonsteroidal anti-inflammatory drugs, rest, modification of daily activities, physical therapy approaches, range of motion and strengthening exercises, subacromial local anesthetic or corticosteroid injections[39–41], can be used to reduce pain, joint stiffness, impaired muscle strength and improve quality of life in patients with SAIS. Recently, low level laser therapy (LLLT) is introduced widely in the management of various rheumatologic and musculoskeletal disorders for its analgesic, anti-inflammatory and biostimulating effects. The LLLT induces cell proliferation, collagen synthesis, protein synthesis, tissue repair, wound healing and pain relief through direct irradiation without thermal response[42–47]. The low level laser treatment is found effective similar to the local corticosteroids injections in patients with subacromial impingement syndrome.[48] LLLT reduces pain[49] and initiates a more rapid course of improvement, both alone and in combination with physiotherapy interventions.[50]

Practical Tip

The low level laser therapy is incorporated with the strengthening exercises of the scapular and shoulder muscles because weakness of these muscles is one of the major causes of subacromial impingement syndrome, especially if the patient is involved in the overhead activities. Therefore, other symptoms such as range of motion (glenohumeral rhythm) would not be improved unless and until the therapist strengthens the rotator cuff muscles and scapula stabilizers (serratus anterior, rhomboid, middle and lower fibers of the trapezius).

Extensor Carpi Radialis Brevis Tendinitis or Tennis Elbow

Lateral epicondylitis or Tennis Elbow is a common disorder with a prevalence of at least 1.7%[51, 52] and occurring most often between the third and sixth decades of life. Despite of availability of wide range of conservative treatment, the patients with lateral epicondylitis do not show significant long term relief in the signs and symptoms. The condition is largely self-limiting, and symptoms seem to resolve between 6 and 24 months in most patients.[53] The effectiveness of low level laser is dose dependent,[54] and the wavelength for tennis elbow may be used from 630 nm to 1064 nm (Fig. 18.12). The effect of low level laser on the collagen tissues is found to be anti-inflammatory and biostimulatory.[55]

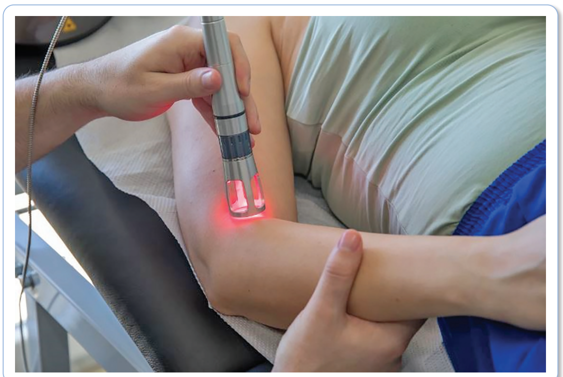


Figure 18.12: Probe laser on lateral epicondyle, the optical head is directed on the treatment area.

Carpal Tunnel Syndrome

Median nerve which passes through the tunnel at the wrist often gets compressed either due to narrowing of the tunnel or inflammation in the flexor tendons that pass through it. Fewer patients may have involvement of both the sides.[56] Carpal tunnel syndrome (CTS) is characterized by numbness, tingling sensation, paresthesia and weakness. The patients are managed with the conservative treatment ranging from ultrasound, cryotherapy, exercises, bracing, and steroid injections to surgical decompression (carpal tunnel release). However, only 0.7% of a general population may require surgery.[57] The use of 632.8 nm, He-Ne laser with continuous mode at 15 mW and 904 nm, infrared laser with pulse mode at 9.4 mW on the affected hand is found effective in reducing pain and symptoms of patients with CTS.[58] The low level laser therapy in comparison to the open carpal tunnel release is found less effective,[59] however, LLLT has proven to be an effective and noninvasive treatment modality for CTS especially for early and mild-to-moderate cases when pain is the main presenting symptom (Fig. 18.13). However, surgery could be preserved for advanced and chronic cases.

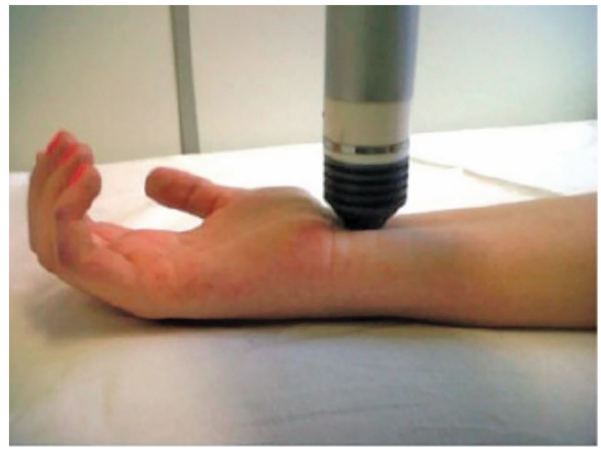


Figure 18.13: Probe laser beam on the carpal tunnel

APPLICATION PARAMETERS

Power

Power is the energy of light per unit time, such as the energy delivered by a laser. Power is, actually, the rate at which energy flows from the output coupler to the laser applicator. It is measured in Watts or milliwatts. The lasers used in the physiotherapy practice have the power range from 5 mW to 500 mW and are classified as class IIIB. Laser apparatuses, usually have fixed power, however, it can be adjusted accordingly. Low power laser requires longer application time to deliver the same amount of energy as high power laser.

Power Density

Power density is the power per unit area also known as irradiance. It is, actually, the power (W) emitted from the output coupler guided by the fiber optic cable and applied on the laser applicator of fixed size (cm^2). Therefore, the power which is being emitted from the applicator is the power density measured in the Watt per centimeter square (W/cm^2).

Power density = Power (W)/size of applicator (cm^2) = W/cm^2

Energy

Energy is the power multiplied by the time of application and is measured in Joules.

Energy = Power (W) × Time (s) = W/s or J

Energy Density

Energy density is the laser energy applied on the treatment area. Energy density is measured in joule per centimeter square.

Energy density = Energy (J)/irradiation area (cm^2) = J/cm^2

In a pulsed laser, the beam is separated in multiple peaks of emission. All these pulses have discrete values of energy. The average energy is the total energy in each pulse divided by the beam size on a given surface. If the average power and the rate at which it emits pulses is known, then the energy of each pulse can be determined.

Energy density = average power/repetition rate (Hz) x beam area (cm^2) = J/cm^2

Must Know

Low energy densities are used for the acute and superficial conditions as these doses are thought to be stimulating. Higher energy densities are recommended for the chronic and deeper conditions as these are suppressive and can be damaging for the acute conditions.

Treatment Doses

Most of the laser devices come with the preset program for various pathological conditions, however, many of them allow the clinicians to select energy or energy density. Energy density is the parameter of choice for laser dose used most often by the clinicians. There are no standardized laser dose recommendations; however, low energy density is suitable for the acute and superficial conditions and higher energy densities are required for the chronic and deep conditions.

Doses that are frequently used in the red wavelength for fairly superficial diseases tend to be in the region of 4 J/cm^2 with a range of 1 to 10 J/cm^2. Doses of the near-infrared wavelengths that tend to be employed for deeper disorders can be higher than these values, i.e., in the 10 to 50 J/cm^2 range. The treatment sessions are repeated on alternate days or daily based on the conditions. Total treatment can be given for period of two weeks. For the treatment of wound healing, a range of energy densities from 01 J/cm^2 to 12 J/cm^2 is commonly used.[60] The treatment should be initiated with the lower end of the recommended range and can be increased in subsequent sessions if the prior sessions were well tolerated. Energy density suggestions based on the conditions are mentioned in the Table 18.2.

The penetration of the photons into the tissues can be maximized if a range of wavelength of laser is near-infrared. The optimum wavelength has been estimated to be around 810 nm.

TABLE 18.2: Doses for various conditions[35]

Types of condition	Suggested treatment dose range, J/cm^2
Soft tissue healing	5–16
Fracture healing	5–16
Arthritis – Acute	2–4
Arthritis – Chronic	4–8
Lymphedema	1.5
Neuropathy	10–12
Acute soft tissue inflammation	2–8
Chronic soft tissue inflammation	10–20

Source: Doses for various conditions taken from Michelle H. Cameron. Physical agents in rehabilitation from research to practice, p-297. Fourth edition. Elsevier.

INDICATIONS

- Pain
- Skin lesions and chronic wounds
- Non-healing fractures
- Bursitis—Subacromial bursitis, prepatellar bursitis, infrapatellar bursitis.
- Tendinitis—Supraspinatus tendinitis, infraspinatus tendinitis, subscapular tendinitis, bicipital tendinitis.
- Arthritic pain.
- Ligamentous sprain—Anterior cruciate ligament, medial collateral ligament, lateral collateral ligament, anterior talofibular ligament, coracohumeral ligament, deltoid ligament.
- Muscle strain—Extensor carpi radialis brevis, gluteus maximus, minimus and golfer's elbow.

PRECAUTIONS

Laser unlike ordinary light emits a beam that is completely focused. Absorption of laser energy by the eye can produce a burn, causing partial or complete loss of vision. As a precautionary measure, the therapist should wear goggles of an appropriate optical density. The practitioner must ask for the goggles from the manufacturer while purchasing the laser equipment. However, single pair of the goggles may not be appropriate for all the wavelengths of laser. The patient should not be allowed to see the laser beam during the treatment session or he or she may be given goggles to wear during the entire session.

CONTRAINDICATIONS

- Pregnant women
- Unclosed fontanels of children
- Cancerous lesion, infected tissues, malignancy
- Cornea
- Endocrine glands
- Hemorrhagic area
- Areas of deficient sensation
- Epiphyseal plates of children
- Sympathetic ganglion
- Vagus nerve
- Mediasternum

APPLICATION PROCEDURE

- Check all the contraindications and take necessary precautions needed before commencing the treatment.
- Place the patient in a comfortable position.
- The part which is being treated should be well supported and exposed.
- Explain the procedure to the patient and also instruct not to see the beam of the laser.
- Most of the laser equipment are designed to have list of conditions with preset frequency, time and energy according to the conditions, however, manual setting options are also available if the therapist wants to modify it.
- The time and frequency required for pain relief is 16–20 seconds and 5–20 pulses per second respectively and for wounds 20–30 seconds and 20–80 pulses per second.[61]
- There are only three valid irradiation techniques for LLLT in tendinopathies:
  i. Direct irradiation of the tendon
  ii. Irradiation of trigger points
  iii. Irradiation of acupuncture points.

- For scanner, direct the laser beam to the treatment area and then activate the laser by pressing the start button. A light will stay on for the duration as selected.
- For probe laser, the probe is paced directly over the treatment area and remains constant over the area throughout the session till the end of the treatment.

Summary

- Low power LASER is the form of light energy, within the red visible and near infrared band of the electromagnetic spectrum. It differs from ordinary light in terms of beam, consistency, coherence, and single wavelength.
- Class IIIB laser with a wavelength of 600 to 1000 nm and power output of 5 to 500 milliwatt produces significant therapeutic effects in the tissues and is used in the physiotherapy practice for reducing pain, inflammation, edema, and promoting healing of wounds. These types of lasers are called cold, low intensity, low power lasers.
- Laser energy produced in the lasing cavity consists of partial and complete optical reflector surface, high voltage source, and laser output optical cable.
- Lasing material placed in the cavity is brought into its one of the upper energy states (population inversion) from the ground state with the help of high intensity flash lamp.
- The atoms of the medium remain for a short period of time in the higher state and fall into the lower state known as metastable state. The atoms release extra energy in the form of photon of light called spontaneous emission while falling into the metastable state.
- In the lasing cavity, the photon collides with an excited atom and produces two identical photons. These two identical photons collide with another excited atom either at the upper higher energy tier or at the metastable state and produce four identical atoms, then eight and so on. This process of producing identical photons is called stimulated emission.
- The photons emitted in the lasing cavity get reflected back and forth on the mirror and further amplify the light and produce intense photon resonance.
- The emitted photons eject through the partial mirror into the fiber optic cable, i.e., a threadlike filament composed of glass into the treatment surface, where they are eventually transmitted into the tissues.
- There are three properties of laser—coherence, monochromaticity, and collimation that distinguish it from incandescent and fluorescent light. The laser light from the optic cable may either be transmitted, or reflected or refracted or absorbed in the tissues.
- The depth of penetration of laser depends upon its wavelength; the higher the wavelength, the greater the depth of penetration. Hence, the infrared laser with the wavelength of 1064 nm transmits energy up to 1.5 cm, whereas He-Ne laser with the wavelength of 632.8 nm transmits laser light only up to 3 mm.
- There are four types of lasers used in the physical therapy practice, Ruby, He-Ne, Gallium arsenide and Infrared laser. All these types of lasers produce more or less similar physiological effects, however, differ in the depth of penetration.
- The photons of specific wavelength emitted by the laser are absorbed by the chromophore, an endogenous compound. Water, melanin, and hemoglobin are three primary endogenous cutaneous chromophores.
- The studies have shown that the chromophores receive the laser light and cause significant biochemical changes at the cellular and subcellular levels, including ATP and RNA production, stimulation of mitochondria, dissociate nitric oxide from cytochrome c oxidase, increase growth factors, increase metabolism, enhance neovascularization, promote angiogenesis and increase collagen synthesis.
- Laser energy is most commonly used for improving wound healing and collagen synthesis; and reducing inflammation, edema, and pain.

References

1. Kleinkort JA and Rolly JA; Laser Acupuncture: its uses in physical therapy. Am J Acupuncture 12:51,1984
2. Susan L Michlovitz, Thermal agents in rehabilitation, 3rd edition, CPR, FA Davis Company, Philadelphia, pp. 255-262.
3. Bloom AL: Gas Laser John Wiley and Sons, New York, 1971, pp 1-24.
4. Electrotherapy, Endurance Based Practice, edited by Sheila Kitchen, 11th edition, Churchill Livingstone, pp 171-172.
5. Physical agents, A comprehensive Textbook for Physical Therapist, Bernadette Hecox, Tsega Andemicael Mechreteab, Joseph Weisberg, Appleton and Lange Norwalk, Connecticut, PP391.
6. Susan L, Michlovitz, Thomas P. Nalan Jr., Modalities for therapeutic intervention, 4th edition, CPR, Jaypee Brothers, New Delhi, p-145
7. PJ Kolari, O Airaksinen: Poor penetration of infra-red and helium neon low power laser light into the dermal tissue. Acupunct Electrother Res. 1993 Jan-Mar;18(1):17-21. PMID: 8098894. doi: 10.3727/036012993816357566.
8. Husain, Z.; Alster, T.S. The role of lasers and intense pulsed light technology in dermatology. Clin. Cosmet. Investig. Dermatol. 2016, 9, 29–40. [CrossRef].
9. Castel MF. A clinical guide to low power laser therapy, Physio Technology Ltd- Medelco, Downsview, 1985.
10. Mester E, Mester AF, Mester A. the biomedical effects of laser application, Lasers in Surgery and Medicine. 1985; 5:31-39.
11. Aubry JR. Clinical low power laser therapy, Montreal Nov. 1985.
12. Chung, H.; Dai, T.; Sharma, S.K.; Huang, Y.-Y.; Carroll, J.D.; Hamblin, M.R. The nuts and bolts of low-level laser (light) therapy. Ann. Biomed. Eng. 2012, 40, 516–533.
13. A Topping, D Gault, A Grobbelaar, R Sanders, C Green, C Linge . Does low penetration of human skin by the normal mode ruby laser account for poor permanent depilatory success rates? Lasers Med Sci. 2001;16(3):224-9. doi: 10.1007/pl00011359. Lasers Med Sci. 2001;16(3):224-9. doi: 10.1007/pl00011359. PMID: 11482822.
14. Laser Fundamentals by William, Thomas Silfvast- Cambridge University Press 1996 pp 547-549.
15. Basant Kumar Nanda, Electrotherapy Simplified 2nd edition, Jaypee, New Delhi, pp425.
16. Goldman L, Rockwell JR, Laser in Medicine. New York; Gordan & Breach 1971
17. Ehrreich SJ, Furchgott RF. Relaxation of mammalian smooth muscles by visible and ultraviolet radiation. Nature. 1968; 218(5142):682–624. [PubMed: 5655961].
18. Carrera M, Pereiraa MC, Bacellar de Pinho C, Medradoa ARP, de Araújo Andradec Z, de Almeida Reis SR. Influence of 670 nm low-level laser therapy on mast cells and vascular response of cutaneous injuries. J Photochem Photobiol B: Biology 2010;98:188-192.
19. Basford JR: Low energy laser therapy: controversies and new research findings, Laser Surg Med 9:1-5,1989.
20. Pourreau-Schneider N, Ahmed A, Soudry M, et al. Helium-neon laser treatment transforms fibroblasts into myofibroblasts. Am J Pathol. 1990; 137:171–178.
21. Yu W, Naim JO, Lanzafame RJ. Effects of photostimulation on wound healing in diabetic mice. Lasers Surg Med. 1997; 20(1):56–63. [PubMed: 9041509]
22. Dadpay M, Sharifian Z, Bayat M, Bayat M, Dabbagh A. Effects of pulsed infra-red low level-laser irradiation on open skin wound healing of healthy and streptozotocin-induced diabetic rats by biomechanical evaluation. J Photochem Photobiol B. 2012; 111:1–8. [PubMed: 22494918].
23. E. Mester, B. Szende and P. Gartner, The effect of laser beams on the growth of hair in mice, Radiobiol Radiother (Berl) 9 (1968) 621-6.
24. Michael R. Hamblin, Department of Dermatology, Harvard Medical School, BAR 414, Wellman Center for Photomedicine, Massachusetts General Hospital, 40 Blossom Street, Boston MA 02114.
25. Mester E, Mester AF, Mester A. The biomedical effect of laser application. Laser in surgery and medicine. 1985;5;31-39.

26. Haina D, Brunner R, Landthalet M, et al. Animal experiments on light-induced wound healing. Laser in Biomedical Research 1973;4:1-3.
27. Mester E. Spiry R, Azende B, et al. Effect of laser rays on wound healing. Am J Surg 1971; 122:532-535.
28. Surinchak J. Alago M, Bellamy R, et al. Effects of low level energy laser on the healing of full thickness skin defects. Lasers in Surg Med 1983;2:267-274.
29. Kana J, Hutschenreiter G, Haina D, et al. Effects of low density laser on healing of open skin wounds in rats. Arch Surg 1981; 116: 293-296.
30. Kovscs I, Mester E, Gorog P. laser-induced stimulation of the vascularization of the healing would- an ear chamber experiment. Experimentia 1974;30:341-343.
31. Adel J. Hussein, Abdalbari A Alfars, Mohsin AJ Falih, Al-Nawar A Hassan. Effects of low level laser on the acceleration of wound healing in rabbits. N Am J Med Sci. 2011 Apr; 3(4): 193–197.
32. Qianqian Chen, Jichun Yang, Huinjan, Yingxin LI, Haixia Qiu, Ying GU, Hua Yang, Dong Xiaoxi, Shi Xiafei, Bochen Che, and Hongxiao LI. Optimization of photo-biomodulation therapy for wound healing of diabetic foot ulcers in vitro and in vivo Vol. 13, No. 4/1 Apr 2022/Biomedical Optics Express 2450.
33. Haymo Thiel, DC, Low Power Laser Therapy- and Introduction and a review of some biological effects. The Journal of the CCA/ Volume 30 no.3, September 1986.
34. Essman WB. Studies of helium-neon laser effect upon mouse skin and mouse skin injury. Queen College of the City University of New York, Flushing, NY, unpublished, 1984.
35. Michelle H. Cameron. Physical Agents in Rehabilitation. P-291. Fourth edition. Elsevier.
36. Thornton AL, McCarty CW, Burgess MJ. Effectiveness of low-level laser therapy combined with an exercise program to reduce pain and increase function in adults with shoulder pain: a critically appraised topic. J Sport Rehabil. 2013 Feb;22(1):72-8. Epub 2012 Oct 11).
37. Mohtadi NG, Vellet AD, Clark ML, Hollinshead RM, Sasyniuk TM, Fick GH, et al. A prospective, double-blind comparison of magnetic resonance imaging and arthroscopy in the evaluation of patients presenting with shoulder pain. J Shoulder Elbow Surg. 2004;13:258–65. 10.1016/j.jse.2004.01.003[PubMed].
38. MacDermid JC, Ramos J, Drosdowech D, Faber K, Patterson S. The impact of rotator cuff pathology on isometric and isokinetic strength, function, and quality of life. J Shoulder Elbow Surg. 2004;13:593–8. 10.1016/ j.jse. 2004.03.009 [PubMed)
39. Kromer TO, Tautenhahn UG, de Bie RA, Staal JB, Bastiaenen CH. Effects of physiotherapy in patients with shoulder impingement syndrome: a systematic review of the literature. J Rehabil Med. 2009;41:870–80. 10.2340/ 16501977-0453 [PubMed].
40. Celik D, Atalar AC, Güçlü A, Demirhan M. The contribution of subacromial injection to the conservative treatment of impingement syndrome. Acta Orthop Traumatol Turc. 2009;43:331–5.10.3944/AOTT. 2009.331 [PubMed].
41. Camargo PR, Haik MN, Ludewig PM, Filho RB, Mattiello-Rosa SM, Salvini TF. Effects of strengthening and stretching exercises applied during working hours on pain and physical impairment in workers with subacromial impingement syndrome. Physiother Theory Pract. 2009;25:463–75. [PubMed
42. Michener LA, Walsworth MK, Burnet EN. Effectiveness of rehabilitation for patients with subacromial impingement syndrome: a systematic review. J Hand Ther. 2004;17:152–64. 10.1197/j.jht. 2004.02.004 [PubMed].
43. Enwemeka CS, Parker JC, Dowdy DS, Harkness EE, Sanford LE, Woodruff LD. The efficacy of low-power lasers in tissue repair and pain control: a meta-analysis study. Photomed Laser Surg. 2004;22:323 9.10.1089/ pho. 2004.22. 323 [PubMed].

44. Kulekcioglu S, Sivrioglu K, Ozcan O, Parlak M. Effectiveness of low - level laser therapy in temporomandibular disorder. Scand J Rheumatol. 2003;32:114–8. [PubMed].
45. Khadra M. The effect of low level laser irradiation on implant-tissue interaction. In vivo and in vitro studies. Swed Dent J Suppl. 2005;172:1–63. [PubMed].
46. Woodruff LD, Bounkeo JM, Brannon WM, Dawes KS, Barham CD, Waddell DL, et al. The efficacy of laser therapy in wound repair: a meta-analysis of the literature. Photomed Laser Surg. 2004;22:241–7.10.1089/1549541041438623 [PubMed].
47. Ezzati A, Bayat M, Taheri S, Mohsenifar Z. Low-level laser therapy with pulsed infrared laser accelerates third-degree burn healing process in rats. J Rehabil Res Dev. 2009; 46:543–54.10.1682/JRRD. 2008.09.0121.
48. Kelle B, and Kozanoglu E Low-level laser and local corticosteroid injection in the treatment of subacromial impingement syndrome:Clin Rehabil. 2014 Feb 11;28(8):762-771. [Epub ahead of print].
49. Sebnem Koldas Dogan, Saime AY, and Deniz Evcik conducted a randomized placebo controlled double-blind prospective study to know the effectiveness of low laser therapy in subacromial impingement syndrome).
50. Haslerud S, Magnussen LH, Joensen J, Lopes-Martins RA, Bjordal JM. The efficacy of low-level laser therapy for shoulder tendinopathy: a systematic review and meta- analysis of randomized controlled trials. Physiother Res Int. 2015 Jun;20(2):108-25. doi: 10.1002/pri.1606. Epub 2014 Dec.
51. Shiri R, Viikari-Juntura E, Varonen H, Heliovaara M. Prevalence and determinants of lateral and medial epicondylitis: a population study. Am J Epidemiol. 2006;164: 1065–74. doi: 10.1093/aje /kwj325. [PubMed] [Cross Ref],
52. Peterson M, Elmfeldt D, Svardsudd K. Treatment practice in chronic epicondylitis: a survey among general practitioners and physiotherapists in Uppsala County, Sweden. Scand J Prim Health Care.2005;23:239–41. doi: 10.1080/02813430510031333. [PubMed] [Cross Ref].
53. Smidt N, Lewis M, DA VDW, Hay EM, Bouter LM, Croft P. Lateral epicondylitis in general practice: course and prognostic indicators of outcome. J Rheumatol. 2006;33:2053–59. [PubMed].
54. Bjordal J, Couppé C, Ljunggreen A. Low level laser therapy for tendinopathy. Evidence of a dose-response pattern. Physical Therapy Reviews. 2001;6:91–99).
55. Lopes-Martins R, Penna SC, Joensen J, Iversen VV, Bjordal JM. Low level laser therapy (LLLT) in Inflammatory and Rheumatic Diseases: A review of Therapeutic Mechanisms. Current Rheumatology Reviews. 2007;3: 147–54. doi: 10.2174/157339707780619421. [Cross Ref].
56. Atroshi I, Gummesson C, Johnsson R, Ornstein E, Ranstam J, Rosen I. Prevalence of carpal tunnel syndrome in a general population. JAMA. 1999;282:153–158. [PubMed].
57. Atroshi I, Gummesson C, Johnsson R, McCabe SJ, Ornstein E. Severe carpal tunnel syndrome potentially needing surgical treatment in a general population. J. Hand Surg. Am. 2003;28:639–644. [PubMed].
58. Naeser MA, Hahn KA, Lieberman BE, Branco KF, carpal tunnel syndrome pain treated with low level laser and microamperes transcutaneous electric nerve stimulation: a controlled study, Arch Phys Med Rehabil 2002 (Jul); 83 (7):
59. Elwakil TF1, Elazzazi A, Shokeir H: Treatment of carpal tunnel syndrome by low-level laser versus open carpal tunnel release. Lasers Med Sci. 2007 Nov;22(4):265-70. Epub 2007 Mar 3.
60. Sobanko JF and Alster TS (2008): Efficacy of low level laser therapy for chronic cutaneous ulceration in humans: a review and discussion. Dermatologic surgery: official publication for American Society for Dermatologic Surgery [et al.], 34:991 ~ 1000.
61. Shaw CJ. The effects of low power laser on wound healing: a review of literature. Student paper, New York University Physical Therapy Program, December 1982.

ASSESS YOURSELF

Long Answer Questions

1. Define laser. Explain in detail the production of laser.
2. Describe the characteristics of laser.
3. What are the physiological effects and clinical uses of laser?
4. Describe different types of laser used in the physical therapy practice and their procedure of application.

Short Answer Questions

1. What is the full form of laser?
2. Which type of laser is used in the physical therapy practice?
3. What is a cold laser?
4. Write about lasing cavity in which laser is produced.
5. What is population inversion?
6. What is spontaneous emission?
7. What is stimulated emission?
8. What are the physical characteristics of laser?
9. What are different types of laser?
10. Which class of laser is used in the physiotherapy practice?
11. What is class III laser?
12. What are different types of laser used in the physical therapy practice?
13. What is Ruby laser?
14. What is Helium-Neon laser?
15. What is gallium arsenide laser?
16. What are the physiological effects of laser?
17. How Laser helps in wound healing?
18. What are the clinical uses of laser?

Short Notes

1. Lasing cavity
2. Population inversion
3. Spontaneous emission
4. Stimulated emission
5. Ruby laser
6. Helium-Neon laser
7. Gallium arsenide laser
8. Class III laser
9. Laser in wound healing
10. Treatment doses of laser

Electrotherapy

Principles and Practice

Learning Objectives in the beginning of every Chapter help readers understand the purpose of the chapter.

LEARNING OBJECTIVES

On completion of the chapter, the student will be able to:

- Explain the mechanism of the production of heat in the tissues by the specific range of microwaves.
- Describe the production of microwaves, their behaviors in the tissues and therapeutic effects along with indications and contraindications.

Chapter Outline gives a glimpse of the content covered in the chapter.

CHAPTER OUTLINE

- Introduction
- Production
- Physical Characteristics
- Physiological Effects
- Clinical Uses
- 2450 MHz MWD versus 915 MHz MWD
- Indications
- Contraindications
- Application Procedure

Must Know boxes give an overview of important facts and terms of the concerned topic.

Must Know

Microwave radiation is defined as waves having a frequency of 300–3000 MHz in the electromagnetic spectrum between radiofrequency and shortwave diathermy. There are three types of MW diathermies, 2450 MHz (12.24 cm wavelength), 915 MHz (32.8 cm wavelength) and 434 MHz (69.1 cm wavelength) used in the physical therapy practice. The higher the frequency, the lower the depth of penetration, hence 915 MHz and 434 MHz microwave diathermies produce heating effect up to 5 cm tissue depth directly, whereas, 2450 MHz MWD reaches up to 1.85 cm depth directly.

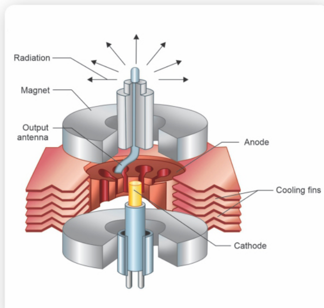
Key Terms are added in each chapter to help the readers understand difficult scientific terms in easy language.

KEY TERMS

Antenna: It is a piece of wire mounted in form of a metal reflector which emits the microwaves in one direction.

Circular director: It produces 100% or maximum energy beneath the periphery of the director.

The book is well illustrated with relevant colorful **Figures**, etc.



Any advancements that have taken place in recent times relevant to study and practice are covered as **Recent Update**.

Recent Update

434 MHz MWD is also introduced and being tried in some countries for its deep heating thermal effects.

Numerous **Tables** have been used in the chapters to facilitate learning in a quick way.

TABLE 3.1: MWD with various frequencies and depth of penetration

Frequency	Wavelength	Depth of penetration
2450 MHz	12.24 cm	1.85 cm
915 MHz	32.8 cm	5 cm
433.9 MHz	69.1 cm	Above 5 cm (still under trial)

Practical Tips have been extensively covered from applied perspective.

Practical Tip

In physiotherapy practice, the significant elongation of the short connective tissues can be achieved if stretching is performed along with hyperthermia of the tissues at the therapeutic range between 41°C and 45°C.

Important takeaway points of respective chapters have been highlighted under **Summary** boxes.

Summary

- Microwave radiation is defined as waves having a frequency of 300–3000 MHz in the electromagnetic spectrum between radiofrequency and shortwave diathermy. There are three types of MW diathermies, 2450 MHz (12.24 cm wavelength), 915 MHz (32.8 cm wavelength) and 434 MHz (69.1 cm wavelength) used in the physical therapy practice. The higher the frequency, the lower the depth of penetration, hence 915 MHz and 434 MHz microwave diathermies produce heating effect up to 5 cm tissue depth directly, whereas, 2450 MHz MWD reaches up to 1.85 cm depth directly.
- The microwave radiation is radiated as a beam from an antenna and is absorbed by water-rich tissues 7000 times effectively than shortwave radio frequency energy. The tissues of high-water contents, like muscles and fluid-filled organs such as eyes, and joints are heated preferentially.

At the end of each chapter, **Assess Yourself** section is given which contains frequently asked questions in exams to help students attain mastery over the subject.

ASSESS YOURSELF

Long Answer Questions

1. Explain in detail the production of microwave diathermy. Write a note on magnetron.
2. Explain in detail the characteristics of microwaves used in the physiotherapy practice. What are the optical laws of radiation?

Short Answer Questions

1. Which device is used to produce the microwaves?
2. What is the magnetron?

Giving extra edge to the study **References** have been included at the end of every Chapter.

References

1. A. Giombini, V. Giovannini, A. Di Cesare, P. Pacetti, Noriko Ichinoseki-Sekinel, M. Shiraishi, Hisashi Naitol and Nicola Maffulli. Hyperthermia induced by microwave diathermy in the macagement of muscle and tendon injuries. Department of Trauma, and Prthopedic Surgery, Keele University School of Medicine, Stoke on Trent, StaffS, UK, June 2008.

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