Ministry of Higher Education and Scientific Research

Al – Zahraa University for Women

College of Medical and Health Technologies

Theoretical

Lecture4

Laser–Tissue Interaction

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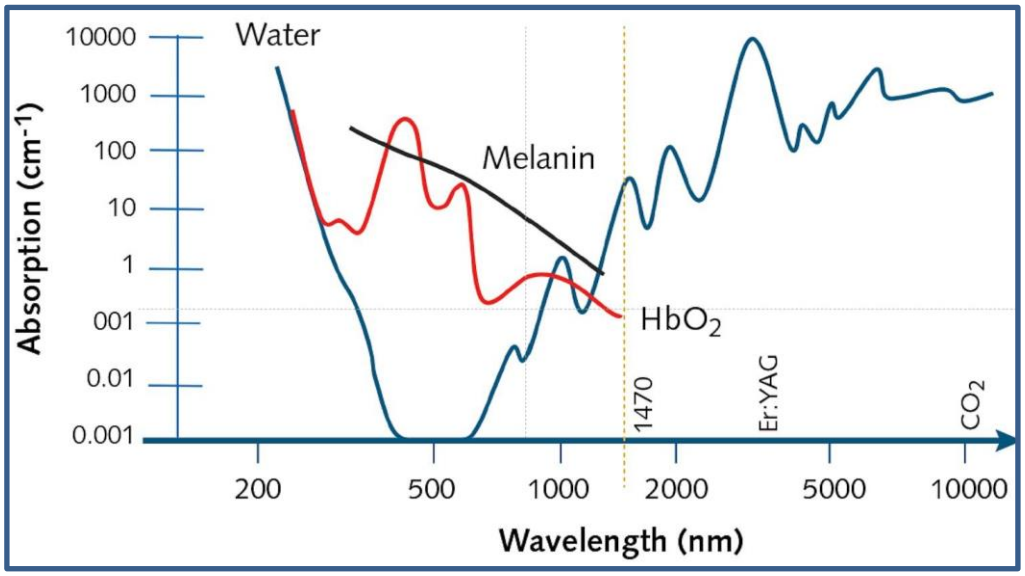
Introduction

Laser tissue interaction is one of the most important topics in medical physics. It describes how laser light interacts with biological tissues when it enters the body. When laser radiation reaches biological tissue, several interactions may occur depending on the laser wavelength, power, exposure time, and tissue characteristics. The three main mechanisms of laser–tissue interaction are:

- **Absorption.**
- **Scattering.**
- **Thermal effects.**

Understanding these mechanisms is essential for the safe and effective use of lasers in medicine and dentistry.

1. Absorption



Definition

Absorption is the process by which biological tissues take up laser energy and convert it into other forms of energy, mainly heat. When laser light enters tissue, certain molecules absorb photons at specific wavelengths. These light-absorbing molecules are called chromophores. Main Tissue Chromophores

The most important chromophores in biological tissues are:

1-Melanin: A pigment found in the skin and hair that absorbs light.

2-Hemoglobin: A protein found in red blood cells that absorbs specific wavelengths of light.

3-Water: A major component of biological tissues that strongly absorbs certain infrared wavelengths.

4-Proteins: Biological molecules that can absorb certain wavelengths of light.

Factors Affecting Absorption

1-Laser wavelength.

2-Tissue composition.

3-Chromophore concentration.

4-Optical properties of the tissue.

Medical Applications of Absorption

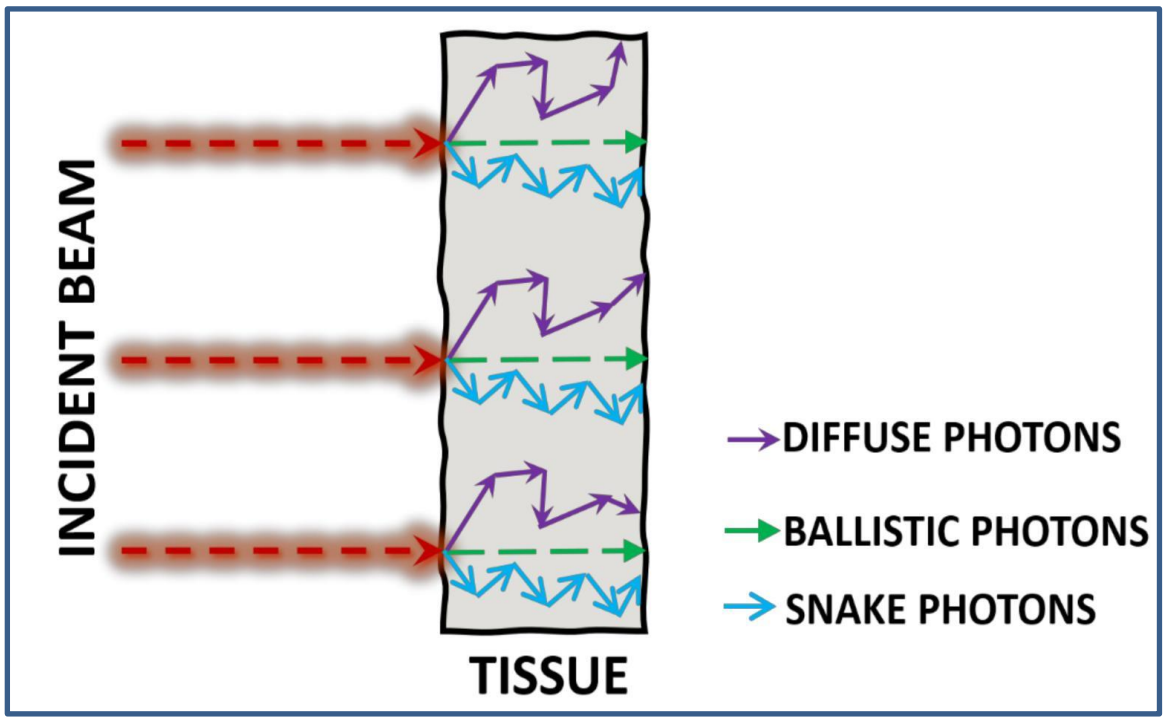
1-Hair removal.

2-Treatment of vascular lesions.

3-Tissue cutting and ablation.

4-Treatment of skin pigmentation.

2. Scattering



Tutorial on the Use of Deep Learning in Diffuse Optical Tomography

Definition

Scattering is the process in which photons change their direction when they interact with structures inside biological tissues.

Unlike absorption, scattering does not necessarily convert light energy into heat.

Types of Scattering

A. Rayleigh Scattering

1-Occurs when particles are much smaller than the wavelength of light.

2-Strongly depends on wavelength.

3-Scattering intensity is approximately inversely proportional to the fourth power of wavelength.

B. Mie Scattering

1-Occurs when particles are similar to or larger than the wavelength of light.

2-It is important in biological tissues.

3-Depends on particle size and optical properties.

Effects of Scattering

1-Changes the direction of light.

2-Reduces direct light penetration.

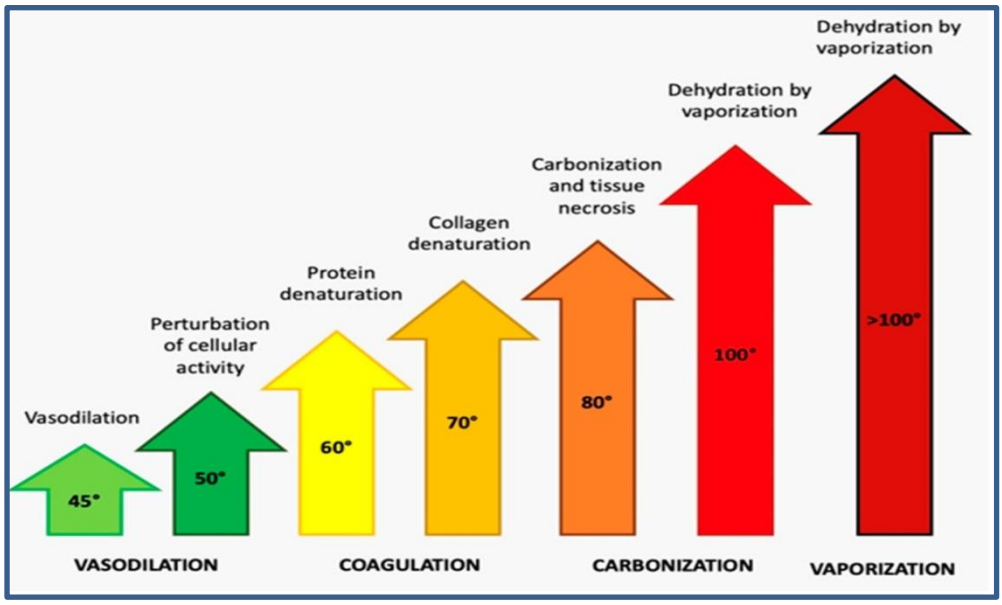
3-Distributes light energy inside tissues.

4-Influences laser penetration depth.

Clinical Importance

Scattering affects the distribution of laser energy inside tissues and influences the accuracy and depth of laser treatments.

3. Thermal Effects



Therapeutic and Adverse Effects of Lasers in Dentistry: A Systematic Review

Definition

Thermal effects occur when absorbed laser energy increases the temperature of biological tissues. The degree of tissue damage depends on temperature, exposure time, and tissue characteristics.

Types of Thermal Effects

1. Hyperthermia

1-Occurs when tissue temperature increases moderately.

2-May cause changes in cellular activity.

3-Its effects depend on temperature and exposure duration.

2. Coagulation

1-Occurs due to tissue heating.

2-Causes protein denaturation.

3-Used in controlling bleeding and sealing small blood vessels.

3. Vaporization

1-Occurs when tissue temperature becomes high enough to vaporize intracellular water.

2-Results in tissue removal.

3-Used in laser cutting and ablation procedures.

4. Carbonization

1-Occurs due to excessive tissue heating.

2-Causes tissue charring.

3-May be an undesirable effect during some medical procedures.

5. Factors Affecting Laser–Tissue Interaction

Several factors determine how laser light interacts with biological tissues.

1. Wavelength

Determines which tissue components absorb the laser energy.

2. Laser Power

Higher laser power can increase the amount of energy delivered to the tissue per unit time.

3. Exposure Time

Longer exposure may increase energy absorption and thermal effects.

4. Spot Size

Affects the distribution of laser energy over the tissue surface.

5. Tissue Characteristics

Different tissues have different water, blood, and melanin contents, which affect their optical properties.

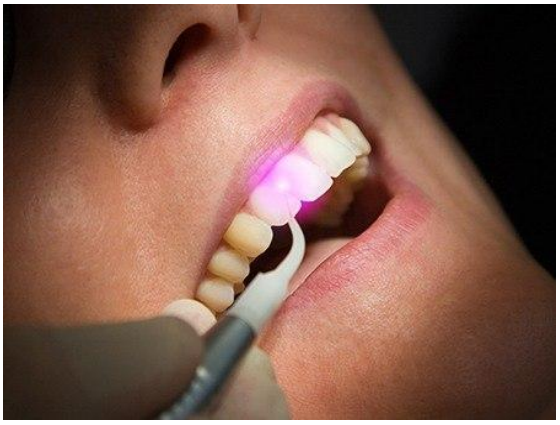
6. Energy Density (Fluence)

Fluence is the amount of laser energy delivered per unit area.

Its unit is: J/cm^2

7. Clinical Applications of Laser–Tissue Interaction





Laser–tissue interactions are widely used in different medical fields.

1-General Surgery: Cutting and removing biological tissues.

Dentistry: Soft-tissue surgery and certain dental treatments.

Dermatology: Hair removal, skin rejuvenation, and pigmentation treatment.

Ophthalmology: Vision correction and treatment of certain eye conditions.

Vascular Medicine: Treatment of abnormal blood vessels.

8. Conclusion

Laser–tissue interaction is essential for understanding the medical applications of laser technology.

The three main mechanisms are absorption, scattering, and thermal effects.

Absorption determines how much laser energy is taken up by the tissue.

Scattering determines how light spreads inside the tissue.

Thermal effects determine the biological changes caused by tissue heating.

Understanding these mechanisms helps improve the effectiveness and safety of laser treatments.

9. Important Questions for Examination

Q1. What are the three main mechanisms of laser–tissue interaction?

Q2. What are the main tissue chromophores?

Q3. What is the difference between absorption and scattering?

Q4. What are the four main thermal effects?

Q5. What factors affect laser–tissue interaction?

Q6. What is the unit of laser fluence ?

Q7. What is the main function of chromospheres?