Dentistry College Medical Physics

Laser in medicine

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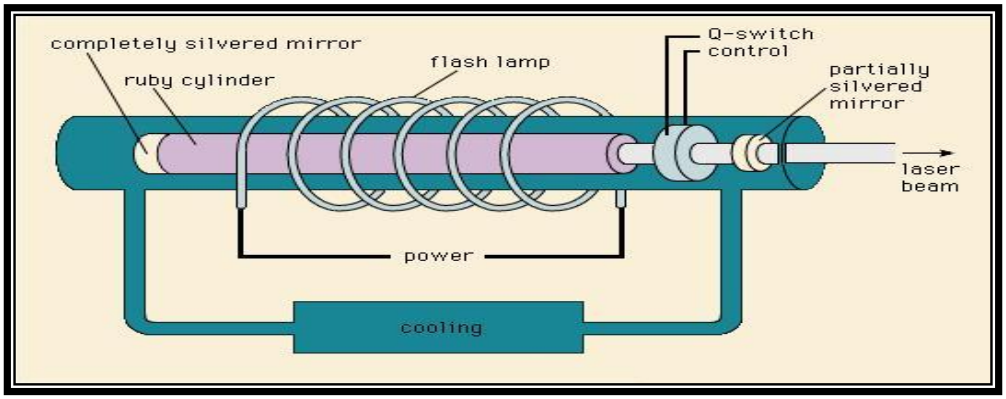
What is laser?

LASER is an acronym for Light Amplification by the Stimulated Emission Radiation.

- The invention of laser source was possible ever since Einstein in 1917 showed theoretically that the process of stimulated emission of radiation must exist to balance the absorption and spontaneous emission of radiation processes.
- In 1950 a group of scientists at Columbia University operated a microwave device that amplified radiation by stimulated emission process. This device was termed (MASER), an acronym for Microwave Amplification by Stimulated Emission of Radiation.
- In 1960, T.H. Maiman produced a laser beam from Ruby crystal. Ruby is an aluminum oxide crystal in which some of the aluminum atoms have been replaced with chromium atoms.



For a ruby laser

- ✓ A crystal of ruby is formed into a cylinder.
- ✓ A fully reflecting mirror is placed on one end and a partially reflecting mirror on the other.
- ✓ A high-intensity lamp is spiraled around the ruby cylinder to provide a flash of white light that triggers the laser action.

The green and blue wavelengths in the flash excite electrons in the chromium atoms to a higher energy level. Upon returning to their normal state, the electrons emit their characteristic ruby-red light.

The mirrors reflect some of this light back and forth inside the ruby crystal, stimulating other excited chromium atoms to produce more red light, until the light pulse builds up to high power and drains the energy stored in the crystal.

Basic Principles of Laser Operation

For the construction of laser system **three** basic requirements, which should satisfy certain conditions, must be provided, these are: -

1. ***An active medium***

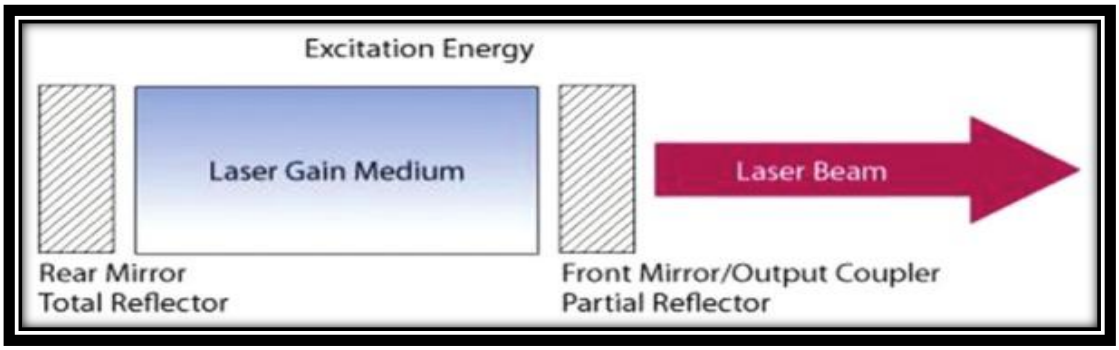
   It represents the collection of atoms, molecules or ions that emit radiation in the optical part of the electromagnetic spectrum. The active medium of a laser might be in gas, liquid or solid form also a semiconductor.

2. ***Pumping energy***

   The energy needed for the excitation procedure in the laser medium.

3. ***Optical resonator***

   The means of the optical feedback in the laser system. This is needed for laser oscillations to provide a highly collimate monochromatic beam that makes the stimulated emission in the **laser** medium so useful.



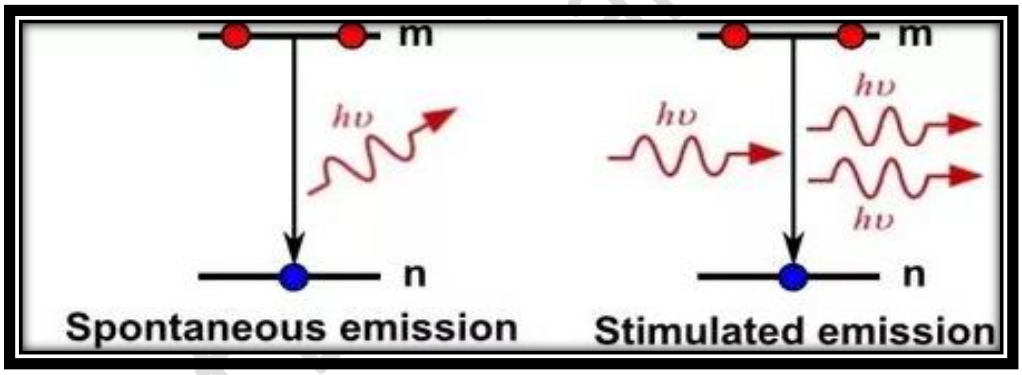
Types of emission

Spontaneous Emission

An excited atom cannot continue having the excess of energy, which it had absorbed, for a long time. Usually it tends to return (**decays**) to a lower energy state by releasing energy, this process occurs spontaneously and randomly.

Stimulated Emission

The excited atom is forced by the incident wave to released photons in the same direction and frequency of incident energy. Radiation emitted by stimulated emission process is coherent and directional.

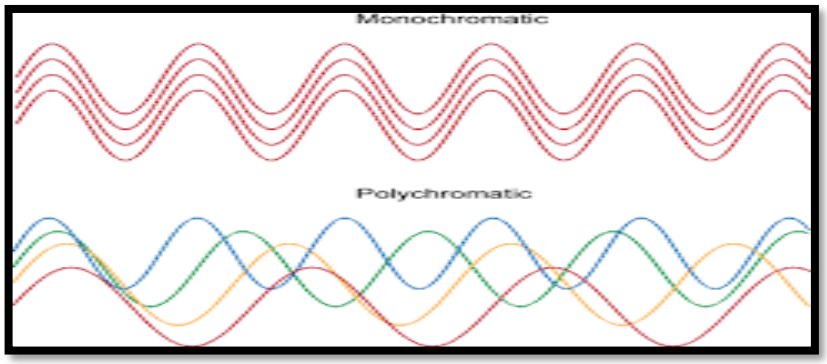


Laser Typical Characteristics

A laser is a unique light source that emits a narrow beam of light of a single wavelength (monochromatic, coherence, directional , and Brightness) The combination of these properties makes laser light focus 100 times better than ordinary light.

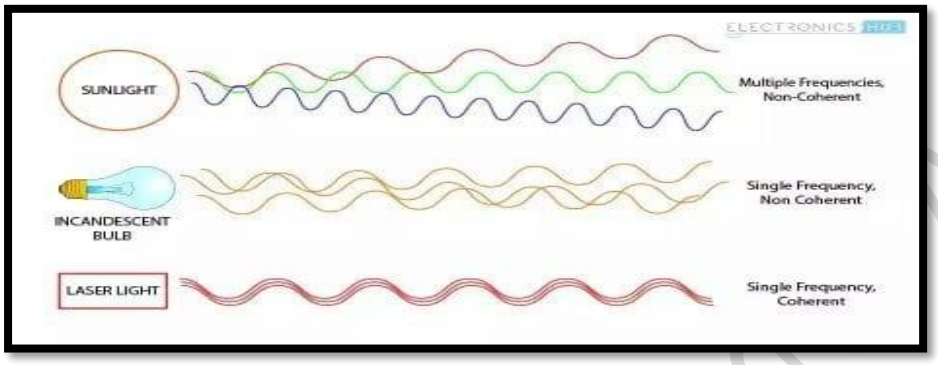
1-*Monochromaticity*

The electromagnetic radiation is single frequency (single-wave length) or single color, a hundred percent monochromatic radiation.



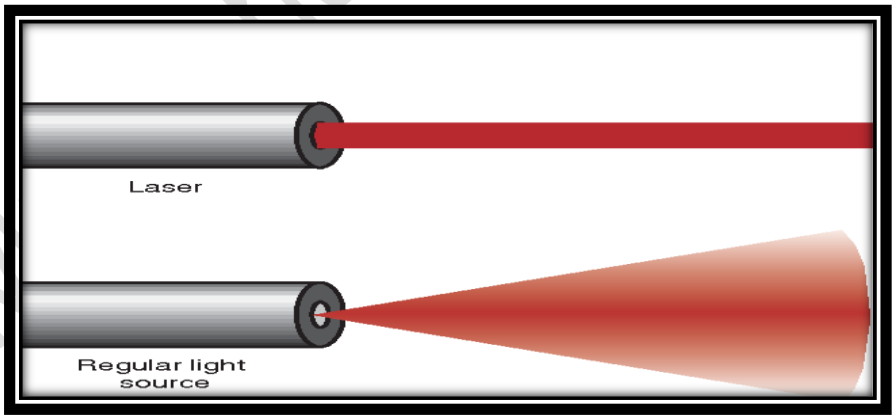
2-*Coherence*

This property is closely related to the wave nature of the light, i.e., the amplitude and the phase. The light from laser source is considered as a beam with frequency (about 10^{14}Hz) it means have wavelength with few micrometer. These beams have the coherence property when they have approximate values of frequency and wavelength.



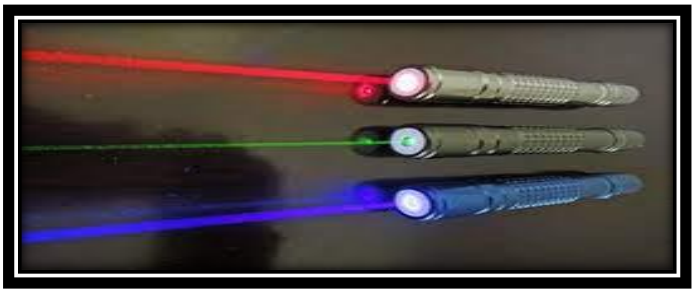
3-Directionality

The most distinguished property of laser light is its directionality. The emission of this source is confined in a collimated, almost parallel beam of very small divergence.



4-Brightness

Laser Brightness is a quantity that depends not only on the total power emitted by the light source but also on its collimation.



Types of medical Lasers that used in medicine:-

i. **Solid-State Laser,** which includes Neodymium Yttrium Aluminum Garnet (Nd: YAG), Erbium Yttrium Aluminum Garnet (Er:YAG), and Ruby Laser.

ii. **Gas Laser**, which includes (He-Ne Laser, Argon ion Laser, and CO_2 Laser).

iii. **Liquid Laser**, which include (Dye Laser).

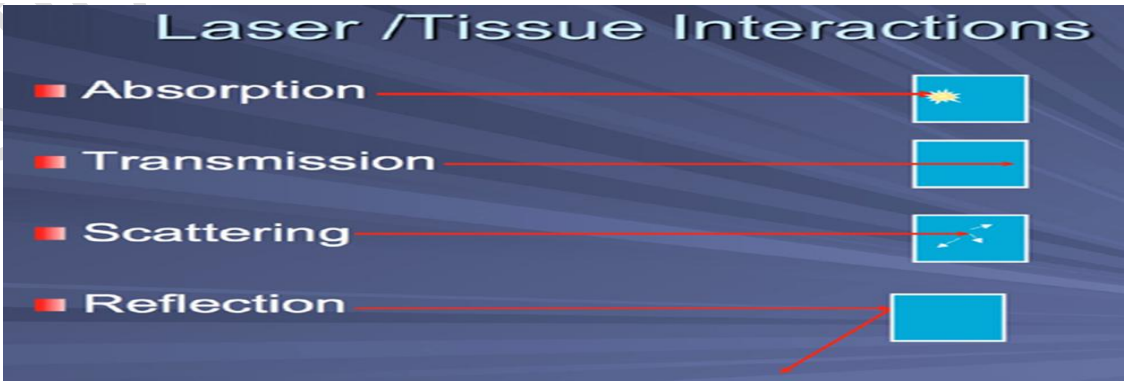
iv. **Semiconductor diode Laser**.

The light energy produced by a laser can have ***four different interactions*** with a target tissue:

1. Reflection.
2. Transmission.
3. Scattering.
4. Absorption.

When a laser is absorbed, it elevates the **temperature** and produces photochemical effects depending on the water content of the tissues. When a temperature of 100°C is reached, vaporization of the water within the tissue occurs, a process called ***ablation***. At temperatures below 100°C, but above approximately 60°C, proteins begin to denature, without vaporization of the underlying tissue.

Absorption requires an absorber of light, termed *chromophores*, which have a certain affinity for specific wavelengths of light. The primary chromophores in the intraoral soft tissue are Melanin, Hemoglobin, and Water, and in dental hard tissues, Water and Hydroxyapatite. Different laser wavelengths have different absorption coefficients with respect to these primary tissue components, making the laser selection procedure-dependent.



Application of laser in medicine

1. *In ophthalmology.* 2. *In Dentistry.* 3. *In tumor treatments.* 4. *In Gynecology.*
5. *In Urology.* 6. *In neurosurgery.* 7. *In angioplasty and cardiology.*
8. *In dermatology and orthopedics.* 9. *In gastroenterology, otorhinolaryngology, and pulmology.*

Laser Dental Applications

Lasers have been used in dentistry since 1994 to treat a number of dental problems. Some dentists are using lasers to treat:

Hard tissue applications

- **Caries removal and cavity preparation**.

- **Re-contouring of bone (crown lengthening)**.

- **Endodontics (root canal preparation, sterilization)**.

- **Laser etching**.

laser etching teeth procedure for Direct Bonding of Orthodontic

Soft tissue applications

- **Bacterial decontamination**.
- **Gingivectomy and Gingivoplasty**.

- **Frenectomy**.

- **Gingival retraction for impressions.**
- **Biopsy incision and excision.**
- **Treatment ulcers and Oral lesion therapy**

- **Coagulation / Hemostasis.**

- **Removal of granulation tissue.**
- **Incisions and draining of abscesses.**

- **Removal of hyperplastic tissues and Fibroma.**

Teeth whitening. A peroxide bleaching solution, applied to the tooth surface, is "activated" by laser energy, which speeds up of the whitening process.

The role of the laser in teeth whitening is to accelerate the activation of hydrogen peroxide (H_2O_2) in the whitening gel .

Upon absorption of laser energy → hydrogen peroxide (H_2O_2) breaks down into → water molecules and oxygen radicals. → The oxygen radicals chemically break down → the larger organic pigment molecules (chromophores) in the enamel matrix into smaller, lighter colored substances through rapid oxidation.

At the same time, the laser-heated bleaching agent increases the penetration of the dentin surface, thus enhancing the whitening effect.

What Types of Lasers are used in Dentistry?

CO_2 laser

The CO_2 laser wavelength well absorbed by water, resulting in rapid soft tissue removal and hemostasis with a very shallow depth of penetration. CO_2 laser best surgical tool that cut soft tissue and stop bleeding from small blood vessel along its path (λ=10600 nm).

It use for:-

- Gingivectomy.
- Frenectomy.
- Fibroma excision
- Remove soft tissue lesion in oral cavity.

Nd: YAG laser

The Nd: YAG wavelength is highly absorbed by the pigmented tissue, making it a very effective surgical laser for cutting and coagulating dental soft tissues, with good hemostasis. In addition to its surgical applications the using of the Nd: YAG laser in hard tissues

In soft tissues	*In* hard tissues
• Gingivectomy. • Frenectomy. • Biopsy.	-Vaporizing decay(caries) - Etching enamel and dentin. -Desensitizing exposed root structure and creating temporary analgesia
• Ulcer • Incising and draining procedures.	

Diod laser

The active medium of the diode laser is a solid state semiconductor which produces laser wavelengths, ranging from approximately 810 nm to 980 nm. All diode wavelengths are absorbed primarily by tissue pigment (melanin) and hemoglobin. Conversely, they are poorly absorbed by the hydroxyapatite and water present in the enamel. Specific procedures include:-

- aesthetic gingival re-contouring.
- soft tissue crown lengthening.
- removal of inflamed and hypertrophic tissue.
- Diode lasers are used in laser teeth whitening.

Erbium laser

It is Solid state laser; the erbium wavelengths have a high affinity for hydroxyapatite and the highest absorption of water in any dental laser wavelengths. Consequently, it is the laser of choice for treatment of dental hard tissues, In addition to hard tissue procedures, erbium lasers can also be used for soft tissue ablation, because the dental soft tissue also contains a high percentage of water. it remove caries tissues from decay teeth

Reshape gum tissue

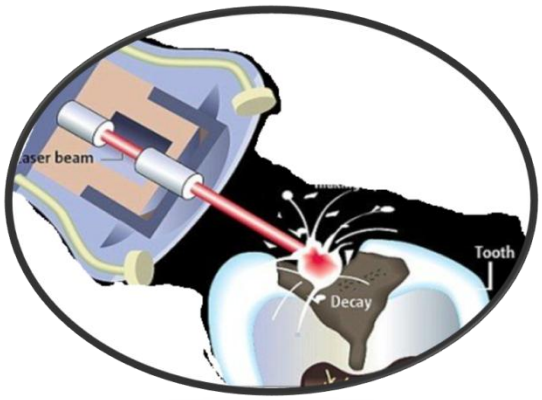
Laser gum reshaping is a quick, nearly painless treatment that is designed to correct the gum line and improve the appearance of the smile. During laser gum reshaping treatment, the gums are numbed and a special dental laser is used to gently remove excess gum tissue and contour the gum line. This procedure painless or minimally uncomfortable, because the dental laser produces minimal trauma to the tissue and cauterizes as it cuts, allowing for quick recovery and reduced risk of infection.

CO_2 laser use for Reshape gum tissue

Laser Drill

A dental drill used to carefully remove the decay and debris from the damaged tooth. This usually involves some vibrations which can cause the tooth's natural structure to weaken. By using a dental laser instead, the decay is removed without uncomfortable vibrating and is even generally able to skip the need for numbing (unless requested).

Lasers are also able to reduce sensitivity for those with sensitive teeth and are the most efficient way of completely removing the bacteria from the tooth. Special for cases like root canal therapy – where the tooth is filled with infected pulp that requires removal.



* Er:YAG use as Laser Drill

Benefits of Dental Lasers

1. **They are Silent**
2. **Less Pain**
3. **Less Dental Trauma**
4. **Lower Chance of Infection**
5. **Faster Dental Procedure**
6. **Safe for Orthodontic Devices**

Laser type Wavelength

Argon ion 488-514.5 nm

KTP 532 nm

He-Ne 632.8 nm

Diode laser 635, 670 nm……Diode laser 810, 810 nm……..Diode laser 980 nm

Nd:YAG 1064 nm

Ho:YAG 2100 nm

Er,Cr:YSGG 2790 nm

Er:YAG 2940 nm

CO2 9300, 9600, 10600 nm