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# LASERS IN PROSTHODONTICS

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# Introduction

No other scientific discovery of the 20th century has been demonstrated with so many exciting applications as laser. The basic concepts of laser were first given by an American scientist, Charles Hard Townes and two Soviet scientists, Alexander Mikhailovich Prokhorov and Nikolai Gennediyevich Basov who shared the coveted Nobel Prize (1964). However, Theodore H. Maiman of the Hughes Research Laboratory, California, was the first scientist who experimentally demonstrated laser by flashing light through a ruby crystal, in 1960.

The word laser is an acronym for the most significant feature of laser action: *light amplification by stimulated emission of radiation*. There are many different kinds of laser, but they all share a crucial element: Each contains material capable of amplifying radiation. This material is called the gain medium because radiation gains energy passing through it. The physical principle responsible for this amplification is called stimulated emission and was discovered by Albert Einstein in 1916.[1]

A device called MASER (microwave amplification by stimulated emission of radiation) based on this principle was first operated in the microwave regime. The laser is an extension of this principle to the visible part of the electromagnetic spectrum.

A laser is a device that amplifies light and produces a highly directional, high intensity beam that most often has a very pure frequency or wavelength. It comes in sizes ranging from approximately one tength the diameter of a human hair to the size of a very long building.[2]

Today, lasers impact almost every aspect of life, from medicine to manufacturing, from communications to measurement, and from research and analysis to entertainment. This is ironic for a device that was initially described as a ‘solution looking for a problem’. They can easily drill holes in the most durable of materials and can weld detached retinas within the human eye. They are a key component of some of our most modern communication systems and are the “phonograph needle” of our compact disc players. They perform heat treatment of high-strength materials, such as pistons of our automobile engines, and provide a special surgical knife for many types of medical procedures. They act as target designators for military weapons and provide for the rapid check-out we have come to expect at the supermarket. What a remarkable range of characteristics for a device that is in only its fifth decade of existence! In fact, during its first 50 years, the laser has been nothing short of revolutionary. We can only wonder what the next 50 years will bring.

The first lasers were developed in 1964 and, almost immediately, the desire to use this new technology in medical applications began.

The general acceptance today of the role of soft tissue surgical lasers in many medical specialties by patients and by physicians allows surgeons to operate in a partially or completely bloodless field as a suitable alternative to traditional surgical treatment regimens.

This acceptance of lasers as viable alternatives to traditional methods in medicine was one of the events that created an explosion of interest in the last decade in the role of lasers in dentistry. Once thought of as a technology looking for a purpose in dentistry, soft tissue lasers, over the last decade, have evolved from a possible choice to an accepted, presently used methodology. Even though soft tissue lasers have found a niche in medicine and in dentistry, the real hope for many patients and dentists has been the development of a laser that would be able to remove hard tissue in a conservative and safe manner.[3]

Dr Leon Goldman, a dermatologist who had been experimenting with tattoo removal using the ruby laser, focused two pulses of that red light on a tooth of his dentist brother in 1965. The result was painless surface crazing of the enamel.[4]

Studies in the 1970s and 1980s turned to other devices, such as CO2 and neodymium YAG (Nd:YAG), which were thought to have better interaction with dental hard tissues. The medical community in the mid to late 1970s had begun to incorporate lasers for soft-tissue procedures, and oral surgeons added the technology in the early 1980s. Frame, Pecaro, and Pick cited the benefits of CO2 laser treatment of oral soft-tissue lesions and periodontal procedures. A portable tabletop model was made available in 1987, and 2 years later Myers and Myers received the US Food and Drug Administration’s permission to sell a dedicated dental laser, a Nd:YAG device.[4]

Hard tissue lasers, first developed in the 1990s, came to the dental marketplace in 1997. These hard tissue erbium lasers have the capability to prepare enamel, dentin, caries, cementum, and bone in addition to cutting soft tissue. The ability of hard tissue lasers to reduce or eliminate vibrations, the audible whine of drills, microfractures, and some of the discomfort that many patients fear and commonly associate with high-speed handpieces is impressive. In addition, these lasers can be used with a reduced amount of local anesthetic for many procedures, which is another feature that makes the hard tissue laser very exciting for needle-phobic patients.

Today, these instruments have evolved from their initial use for all classes of cavity preparations to their ability for removing soft tissue, their usefulness in the disinfection of bacteria within endodontic canals, and most recently, as an alternative to the high-speed handpiece for the removal of bone in oral and maxillofacial surgery.[3]

# History

In 1917, Einstein laid the foundation for the laser when he introduced the concept of stimulated emission; where a photon interacts with an excited molecule or atom and causes the emission of a second photon having the same frequency, phase, polarization and direction. The acronym LASER stands for "Light Amplification by Stimulated Emission of Radiation".

## The First Laser:

**Dr. Theodore Maiman of Hughes Research Laboratories, with the first working laser.**

Theodore Maiman developed the first working laser at Hughes Research Lab in 1960, and his paper describing the operation of the first laser was published in Nature three months later. Since then, more than 55,000 patents involving the laser have been granted in the United States. Today's laser and all of its applications are the result of not one individual's efforts, but the work of a number of prestigious scientists and engineers who were leaders in optics and photonics over the course of history. These include such great minds as Charles Townes at Columbia University, who developed the maser, the precursor to the laser, and Arthur Schawlow at Bell Laboratories, who along with Townes published a key theoretical paper in 1958 that helped lead to the lasers development and who jointly were awarded the first laser patent in 1960.

## The 1950's:

### The Maser :

A predecessor of the laser, called the MASER, for "Microwave Amplification by Stimulated Emission of Radiation", was independently developed in 1954 at Columbia University by Charles Townes and Jim Gordon and in Russia by Nicolay Basov and Alexsandr Prokhorov. These ammonia masers were two energy level gaseous systems that could continuously sustain a population inversion and oscillation. In 1956 Nicolaas Bloembergen proposed a three level solid state maser at Harvard, demonstrated by researchers at Bell Labs that same year.

### Laser Beginnings:

Soon after the maser, Arthur Schawlow and Charles Townes began thinking about ways to make infrared or visible light masers. In 1957 Schawlow and Townes constructed an optical cavity by placing two highly reflecting mirrors parallel to each other, and positioning the amplifying medium in between. In 1958, they published a seminal Physical Review paper on their findings and submitted a patent application for the so called optical maser.

Although the paper rightfully gave Schawlow and Townes recognition as having invented the laser, several others independently came up with the same "open cavity" concept, including Gordon Gould, a graduate student at Columbia University. Gould was also the first to publically use the term laser, for "Light

Amplification by Stimulated Emission of Radiation" at the June 1959 Ann Arbor Optical Pumping Conference.

## Laser in dentistry:

- Nearly, all of the early dental research was performed on ruby laser.
- Dental laser research began in 1963 at the university of California at Los Angeles, school of dentistry with the investigations of Ralph H. Stein and Reidar F. Sognnaes.
- They reported the development of craters and glass like fusion of enamel, and penetration and charring of dentin following a single millisecond pulse of the ruby laser at 500 – 2000 J/sq cm. Stern also suggested that applications of lasers in dentistry depends on fiber optics (1965). He in 1974 also revealed a possible role for laser in caries prevention by showing an increased resistance to acid penetration by enamel.
- The first report of a laser exposure to a vital human tooth appeared in 1965 when Leone Goldman MD applied two pulses of ruby laser on his brother Bernard Goldman. It is an interesting fact that the first laser dentist was a physician and the first dental laser patient was a dentist.
- Taylor and associates in 1965 observed extensive hemorrhagic necrosis and disruption of the odontoblastic layer in the incisors of lab animals.
- Adrian et al in 1971 later confirmed the first report of extensive output injury and destruction with the ruby laser.
- By the end of 1960s, most dental researchers agreed that excessively high energy levels were required for the removal of tooth structure by ruby laser, which would result in sever thermal damage to vital issues in oral cavity.

Development of Carbon Dioxide Laser:

- With rather disappointing results of ruby laser, researchers shifted their focus in search of other useful laser wavelengths.
- Since its wavelength of 9-11 micro meter was well absorbed by the hydroxyapatite enamel, it was thought that it might be suitable for selected surface applications on teeth, such as sealing of pits and fissures, welding of ceramic materials to enamel or prevention of dental caries (Lobene 1968, Stein et al 1972).
- Kantola performed a lot of researches in Finland. In a series of studies employing SEM, X ray diffraction and electron probe microanalysis technique; he determined the physical and chemical transformations in enamel that resulted from exposure to laser. Although these studies confirmed the ability of the $CO_2$ laser to induce resistance to acid penetration of enamel, they also revealed high surface temperatures generated during this process.
- During the same period Melcer and others were actively involved in the clinical application of the $CO_2$ laser for the vaporization of caries. They reported the successful treatment of over 1000 human patients in clinical trials of caries removal by the laser.  Hence this laser prototype showed promise as an alternative to the dental drill.
- At the other end, extensive investigations involving the experimental use of $CO_2$ laser for various surgical applications were reported in medical literature throughout 1960s and 1970s. Pecaro and Garehime of

northwestern university dental school in Chicago presented an extensive account of the benefits of the $CO_2$ laser in oral and maxillofacial surgery.

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- Shortly afterwards, Fisher and Frame of England presented a number of papers on the treatment of benign and premalignant oral lesions with the carbon dioxide laser during the 1980s. The properties of improved hemostasis afforded through tissue ablation with the $CO_2$ laser were first recognized and applied to periodontal surgery by Pick in 1985.
- According to most sources the $CO_2$ showed a number of advantages in its application for soft tissue surgical procedures in the mouth. Hence the research in this era marked a revolutionary advancement towards soft tissue applications of lasers in the mouth.

## Development of Nd:YAG Laser:

- The first report of dental application if the neodymium lasers to the vital oral tissue in experimental animals was that of Yamamoto and others from Tohuku University School of Dentistry in Japan (1974). In a series of experiments he determined that Nd:YAG laser increased the resistance of human enamel to demineralization. Adrian (1977) in his ongoing research showed that pulp is more resistant to injury by the neodymium laser than by the ruby laser. He considered its use on teeth and for dental alloys.

Since then extensive research is in process to establish Nd:YAG laser for various dental applications.

- In May 1990, Myers and Myers developed the first specialized dental laser (pulsed Nd:YAG) called de-lase300. Laser unit and fiber delivery system.

Fig.pulsed Nd:YAG

Laser and soft tissue:

- The first reported application of a laser for maxillofacial surgery was by Lenz who used an argon laser to create a nasoantral window.(Lenz et al, 1977).
- In January 1987, FDA gave the first marketing approval for laser use in oral surgery to the Pfizer Laser Company for a 10W portable $CO_2$ laser unit.

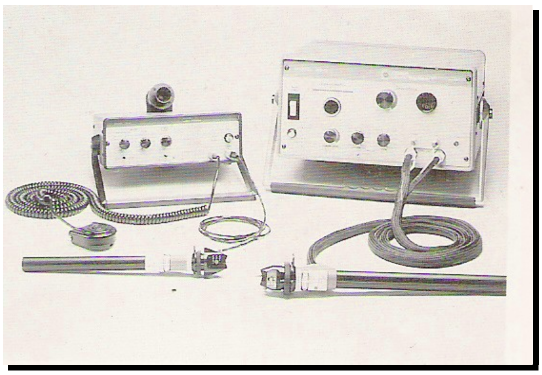


fig. 10w laser on left and 20w laser on right

- Shortly, afterward, number of important paper were presented by Fisher and Frame of England on the treatment of benign and premalignant oral lesions with the $CO_2$ laser during 1980s.
- The properties of improved hemostasis afforded to periodontal surgery by Pick (Pick et al 1985).

**Disadvantages :**

- But periodontal application remained limited to those procedure that could be performed via optical lens delivery systems, that is, treatment of soft tissue surface lesions that could be easily accessed by direct vision in the mouth.

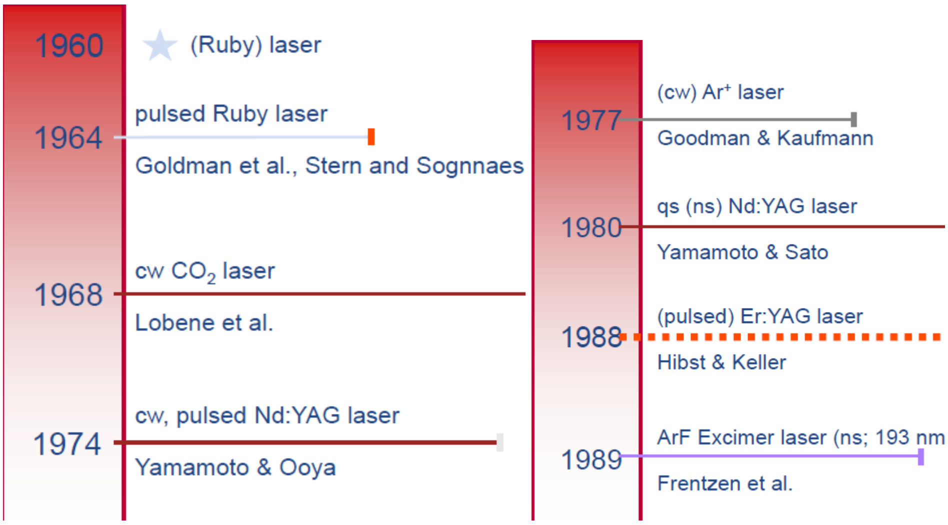
## laser and hard tissue:

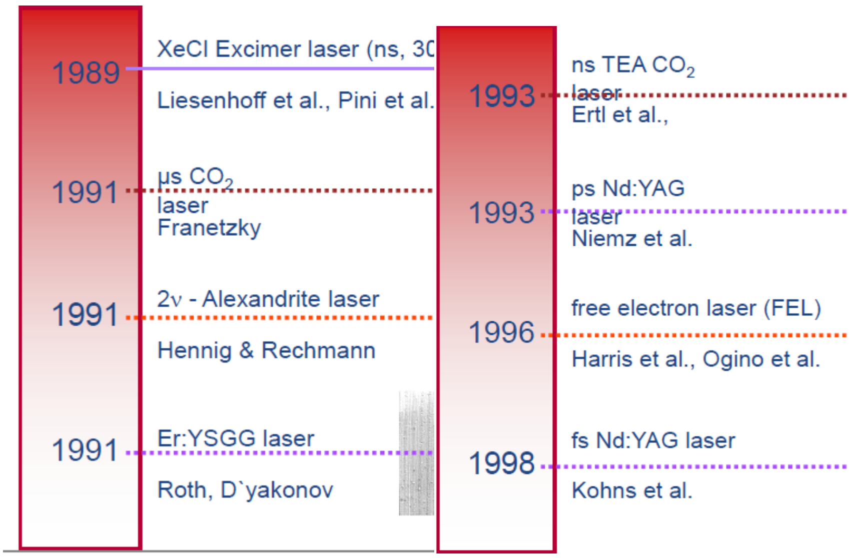
- In 1989, Keller and Hibst, using pulsed erbium YAG-(2940nm) laser, demonstrated its effectiveness in cutting enamel, dentin and bone commercially available in 1995.
- Er,Cr.YSGG, laser become available in 1997.

## Current wavelengths in dentistry:

- Numerous laser wavelengths are being used clinically in dental practices today. The specific parameters of how they are used depend on their individual tissue absorption characteristics, among other factors.

- The soft-tissue surgical lasers are the most widespread. Amongst these Nd:YAG, $CO_2$ and diode lasers are the most prevalent, although the argon, Ho:YAG, Nd:YAP, Er:YAG and Er:YSGG are also used for these purposes.
- The argon laser is used for composite polymerization and tooth whitening.
- Caries removal, cavity preparation and enamel surface modification are the purview of Er:YAG and Er:YSGG lasers.
- Diode lasers are used to perform pulpotomies as an adjunct to root canal treatment.



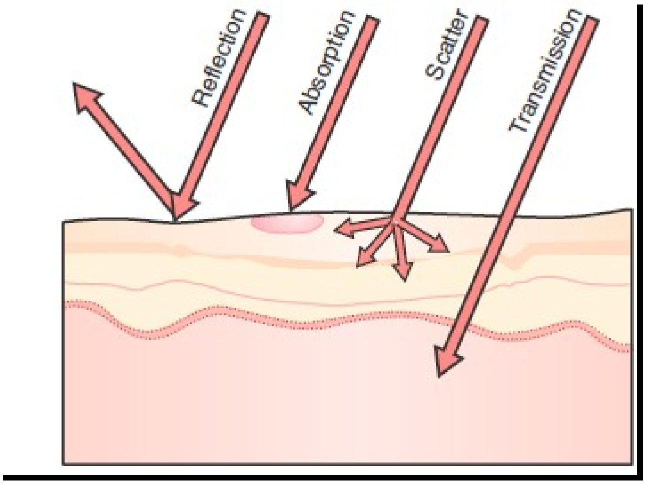




## The biologic rationale for the use of lasers in dentistry

Whenever laser energy is applied to oral tissue, it is incumbent on the dentist (or hygienist) to understand the biologic rationale for its use. Dentists can choose from a variety of wavelengths to use in the oral cavity. A complete understanding of the interaction between each of these different laser wavelengths and the target tissues is essential to ensure optimal treatment results.

Laser light can have four different interactions with the target tissue, depending on the optical properties of that tissue. Oral tissues have complex composition, and these four phenomena occur together in some degree relative to each other.

1) Absorption
2) Transmission
3) Reflection
4) Scattering of the laser beam



**Four potential laser-tissue interactions**

## 1) Absorption:

The first and most desired interaction is the absorption of the laser energy by the intended tissue. The amount of energy that is absorbed by the tissue depends on the tissue characteristics such as pigmentation and water content and on the laser wavelength. Hemoglobin, the molecule that transports oxygen to tissue, reflects red wavelengths, imparting color to arterial blood. It therefore strongly absorbs blue and green wavelengths. Venous blood, containing less oxygen, absorbs more red light and appears darker. Water, the universally present molecule, has varying degrees of absorption of different wavelengths.

Oral tissues have varying amount of water content with enamel (2% to 3%) having least water content followed by dentin, bone, and soft tissue (70%). Hydroxyapatite is the chief crystalline component of dental hard tissues and has a wide range of absorption depending on the wavelength.

In general, the shorter wavelengths (from about 500–1000 nm) are readily absorbed in pigmented tissue and blood elements. Argon is highly attenuated by hemoglobin. Diode and Nd:YAG have a high affinity for melanin and less interaction with hemoglobin. The longer wavelengths are more interactive with water and hydroxyapatite. The largest absorption peak for water is just below 3000 nm, which is at the Er:YAG wavelength. Erbium is also well absorbed by hydroxyapatite. $CO^2$ at 10,600 nm is well absorbed by water and has the greatest affinity for tooth structure.

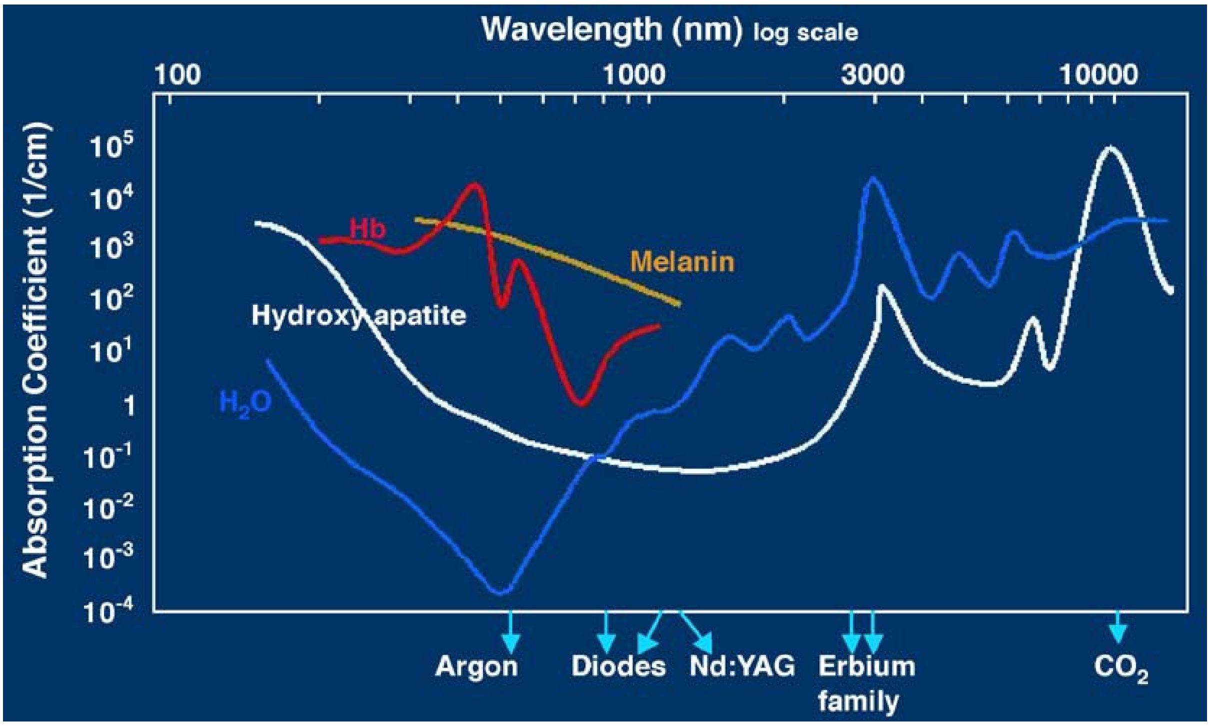


Fig.  Approximate absorption curves of different dental compounds by various wavelengths of dental lasers.

## 2) Transmission

The second effect is transmission of the laser energy directly through the tissue without being absorbed. This effect is highly dependent on the wavelength of laser light.  Water, is relatively transparent to the shorter wavelengths like argon, diode, and Nd:YAG, whereas tissue fluids readily absorb the erbium family and $CO_2$  at the outer surface, so there is little energy transmitted to adjacent tissues. Following Figure depicts this interaction by showing relative depth of penetration in water of various wavelengths.

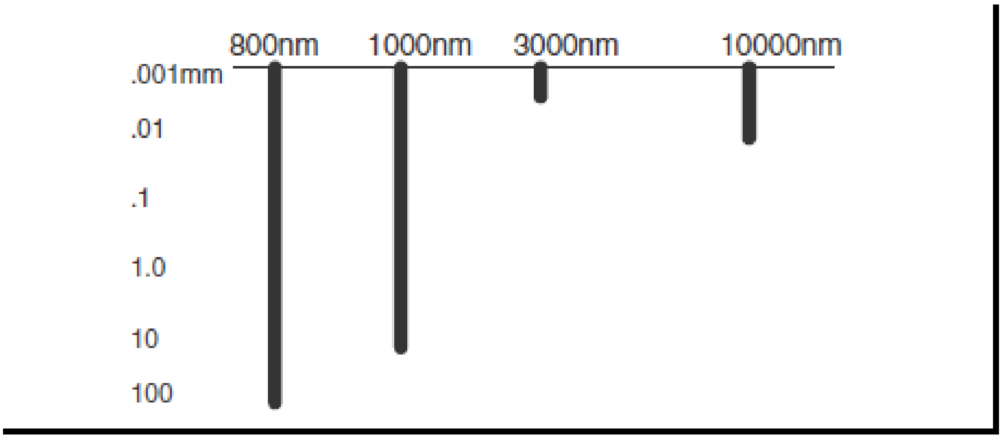



Fig. Relative depth of penetration (in millimetres) of different wavelengths in water. The vertical scale is logarithmic.

The depth of the focused laser beam varies with the speed of movement and the power density. In general, the erbium family acts mainly on the surface, with an absorption depth of approximately 0.01 mm, whereas the 800-nm diodes are transmitted through the tissue to depths up to 100 mm, a factor of 10,000. As another example, the diode and Nd:YAG lasers are transmitted through the lens, iris, and cornea of the eye and are absorbed on the retina.

### 3) Reflection

The third effect is reflection, which is the beam redirecting itself off of the surface, having no effect on the target tissue. A caries-detecting laser device uses the reflected light to measure the degree of sound tooth structure. The reflected light could maintain its collimation in a narrow beam or become more diffuse. The laser beam generally becomes more divergent as the distance from the handpiece increases. However, the beam from some lasers can have adequate energy at distances over 3 m. This reflection can be dangerous because the energy is directed to an unintentional target, such as the eyes; this is a major safety concern for laser operation.

### 4) Scattering of the laser light

The fourth effect is scattering of the laser light, weakening the intended energy and possibly producing no useful biologic effect. Scattering of the laser beam could cause heat transfer to the tissue adjacent to the surgical site, and unwanted damage could occur. However a beam deflected in different directions is useful in facilitating the curing of composite resin or in covering a broad area.

Absorption of the laser light by the target tissue is the primary and beneficial effect of laser energy. The goal of dental laser surgery is to optimize these photobiologic effects[19]. Using the photothermal conversion of energy, incisions and excisions with accompanying precision and hemostasis can be achieved. There are photochemical effects from laser light that can stimulate chemical reactions (eg, the curing of composite resin) and breaking of chemical bonds. A special group of lasers that emit in the ultraviolet ionizing range, the excimers, have enough photon energy to directly break the chemical bond of an organic molecule without any thermal damage[20]. These are being investigated for hard tissue ablation procedures. Certain biologic pigments, when absorbing laser light, can fluoresce, which can be used for caries detection within teeth. A laser can be used with powers well below the surgical threshold for biostimulation, producing more rapid wound healing, pain relief, increased collagen growth, and a general anti-inflammatory effect.

To summarize the tissue interaction effect of a particular machine, several factors must be considered. Each laser has common internal parts but different delivery systems and emission modes. The laser wavelength affects certain components of the target tissue; the water content, the color of the tissue, and the chemical composition are all inter-related. The diameter of the laser beam, whether delivered in contact or noncontact with the tissue, creates a certain energy density—the smaller the beam, the greater the energy density. For example, a beam diameter of 200 μm has over twice as much energy density as a beam diameter of 300 μm. The result of using the smaller fiber is greatly increased thermal transfer from the laser to the tissue and a corresponding increase in absorption of heat in that smaller area. The amount of time that the beam is allowed to strike the target tissue affects the rate of tissue temperature rise. That time can be regulated by the repetition rate of the pulsed laser emission mode as well. The amount of cooling of the tissue by the use of a water or air spray also affects the rate of vaporization.

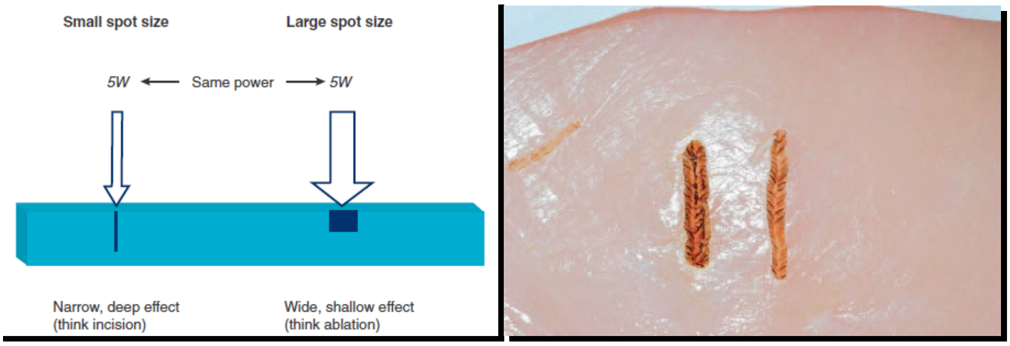



Fig. A graphic representation of the relationship between spot size and fluence.

The same wavelength and power were used but the spot size was changed. On the left, the incision is narrow and deep with a smaller spot size; on the right, the incision is wide and shallow with a larger spot size.

# Tissue Effects of Laser Irradiation:

When radiant energy is absorbed by tissues 4 basic types of interactions or responses can occur:-

1) Photo chemical interactions
2) Photo thermal interactions
3) Photo mechanical interactions
4) Photo electrical interactions

## 1) Photo Chemical Interactions:

The basic principle of the photo chemical process is that specific wavelength of laser light are absorbed by naturally occurring chromophores or wavelength specific light absorption substances that are able to induce certain biochemical reactions at the cellular level. Derivatives of naturally occurring chromophores or dyes can be used as photosensitizers to induce biologic reactions within the tissue for both diagnostic and therapeutic applications. Photochemical interactions are subdivided into;

a) Photodynamic therapy (PDT)
b) Bio stimulation

Photodynamic therapy is the therapeutic use of lasers to induce reactions in tissues for the treatment of pathologic conditions and phosphorescent re-emission or tissue fluorescence which may be used as a diagnostic method to detect light reactive substance in tissue.

## 2) Photothermal interactions:

Radiant light energy is absorbed by tissue substances and molecules become transformed into heat energy which produces this tissue effect. The amount of laser light energy absorbed in tissue depends on a number of following factors that includes

1) Wavelength of radiant energy from the laser
2) Laser parameters such as spot size, power density, pulse duration and frequency.
3) Optical properties of tissue
4) Composition of the target tissue

Photo thermal interactions manifest clinically as photoablation or the removal of tissue by vaporization and super heating of tissue fluids, coagulation and haemostasis and photopyrosis or the burning away of tissue. Depending on the amount of energy delivered, the resultant effect is either coagulation, vaporization or a combination of the two.

Temperature below 60°C generally will manifest as tissue hyperthermia. Between 45-50°C enzymatic changes occurs in form of oedema. Above 65°C protein denaturation occurs accompanied by coagulation of blood elements or proteins. Below 100° C tissue dehydration or desiccation is observed which clinically appears as whitening or blanching of tissue. Temperatures above 100°C produce rapid vaporization of tissue fluids resulting in tissue ablation and shrinkage or contracture of the adjacent area. Continued lasing of the area result in temperature elevation to several hundred degrees leading to tissue vaporization, carbonization and burning.

Pulsed Nd:YAG laser does not cause deep photothermal effects in excision of oral soft tissue. Thermal effects on teeth and bone were compared with laser and electrocautery. Electrocautery showed significantly higher temperature than CO2 and Nd: YAG lasers.

Table: Thermal Interactions of Tissue[21]:

| Temperature(°C) | Tissue Effects |
|---|---|
| 42 -45 | Hyperthermia (transient) |
| > 65 | Desiccation, protein denaturation and coagulation |
| 70 -90 | Tissue welding |
| > 100 | Vaporization |
| > 200 | Carbonization and charring |

## 3) PHOTOMECHANICAL AND PHOTOELECTRICAL INTERACTIONS:

Photomechanical interactions include photodisruption or photodisassociation which is the breaking apart of structures by laser light and photoacoustic interactions which involve the removal of tissue with shock-wave generation. Photo electrical interactions include photoplasmolysis which describes how tissue is removed through the formation of electrically charged ions and particles that exist in a semigasseous high energy state.

# Delivery system

Optimal therapeutic effects result when the wavelength best absorbed by the target tissue is selected for use; however, the choice of the best laser for a certain procedure depends on much more than just matching emission spectra of lasers to absorption spectra of tissues.

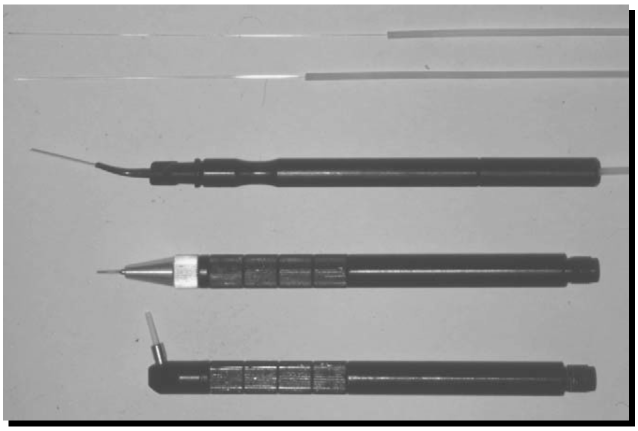
The type of delivery system best able to deliver the wavelength to the target, the composition of the tissue surrounding the target tissue, and the potential for necrosis of the surrounding tissue also must be taken into account.

The field of lasers in general practice essentially began with the introduction of the American Dental Laser (Birmingham, Michigan) dLase 300 neodymium:yttrium-aluminum-garnet (Nd:YAG) laser in 1990. Before the introduction of this instrument, most dental lasers used bulky articulated arms for their delivery systems. These articulated arms were not conducive to the practice of general dentistry, owing to the long learning curve needed to master their use and the difficulty of delivering the laser energy to the entire oral cavity. Articulated arm delivery systems consist of a series of rigid hollow tubes with mirrors at each joint (called a knuckle) that reflect the energy down the length of the tube. These joints exist to allow the delivery arm to be bent and configured in such a way as to bring the handpiece close to the target tissue. The laser energy exits the tube through a handpiece. Strauss [22] described the intraoral use of an articulated arm delivery system. He stated that it is a difficult way to remove discrete lesions within the oral cavity because of the awkward three-dimensional maneuverability of the arm. A second problem with the use of articulated arms is the alignment of the mirrors. To transmit the laser energy efficiently, the mirrors at each knuckle must be aligned precisely. A misalignment of the mirrors could cause a drop-off in the amount of energy transmitted to the handpiece. The mirrors could go out of alignment through the normal use of moving the articulated arm for each new procedure or if the laser is moved from treatment room to treatment room. Articulated arm delivery systems are noncontact systems (ie, the handpiece or its attachments do not come into contact with the target tissue). Dentists are familiar with contact technology: The fissure bur contacts the enamel during tooth preparation. The curette contacts the root surface during scaling and root planing. The scalpel contacts the soft tissue when incising. Using a technology in which there is no contact between the instrument and target tissue can be challenging at first. This is one major reason for a longer learning curve with these instruments compared with contact technology instruments.

Articulated arm delivery system. (Courtesy of DEKA Laser Technologies LLC, Ft. Lauderdale, FL.)

The American Dental Laser dLase Nd:YAG system was the first such instrument to use a fiberoptic delivery system. This fiberoptic technology allows for contact with the target tissue. The fiberoptic cables are attached to a small handpiece similar in size to a dental turbine and are available in sizes ranging from 200 µm in diameter to 1000 µm in diameter. Fiberoptic cables also are relatively flexible. This flexibility allows for easy transmission of the laser energy throughout the oral cavity, including into periodontal pockets. Fiberoptic delivery and articulated arm systems are not the only two delivery systems currently on the market. One manufacturer has developed a hollow waveguide delivery system. In contrast to an articulated arm system, this waveguide is a single long, semiflexible tube, without knuckles or mirrors. The laser energy is transmitted along the reflective inner lumen of this tube and exits through a handpiece at the end of the tube. This handpiece comes with various attachments that the dentist may select, depending on the procedure to be performed, and may be used either in contact or out of contact with the target tissue.

Waveguide delivery system.



Fiberoptic cables of various diameters and handpieces from a $CO_2$ waveguide delivery system.

The final delivery system is the air-cooled fiberoptic delivery system. This type of delivery system is unique to the erbium family of lasers. A conventional fiberoptic delivery system cannot transmit the wavelength of the erbium family of lasers, owing to the specific characteristics of the erbium wavelength. These special air-cooled fibers terminate in a handpiece with quartz or sapphire tips. These tips are used slightly (1–2 mm) out of contact with the target tissue.

Since the introduction of the dLase 300, general practitioners have seen the number of wavelengths and manufacturers available to them, increasing from one manufacturer of one wavelength to eight different manufacturers offering six different wavelengths.

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Wavelengths currently available for sale in the United States

| Wavelength | Manufacturer | Delivery system |
|---|---|---|
| Diode, 810–830 nm | Biolase | Fiberoptic cable |
| | Hoya/Conbio | Fiberoptic cable |
| | Zap Lasers | Fiberoptic cable |
| | OpusDent | Fiberoptic cable |
| | Biolitec* | Fiberoptic cable |
| Nd:YAG, 1064 nm | Biolase | Fiberoptic cable |
| | Lares Research | Fiberoptic cable |
| | Millenium Dental Technologies | Fiberoptic cable |
| Er:Cr:YSGG, 2780 nm | Biolase | Air-cooled fiberoptic/handpiece |
| Er:YAG, 2940 nm | Hoya/Conbio | Air-cooled fiberoptic/handpiece |
| | OpusDent | Hollow waveguide |
| $CO_2$, 10,600 nm | OpusDent | Hollow wave guide |
| | Deka | Articulated arm |

* The wavelength produced by the Biolitec laser is 980 nm; all other diode lasers produce a wavelength of 810–830 nm.