Buffalo Niagara Dental Meeting

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UNDERSTANDING LASERS: FROM THE SCIENCE TO CLINICAL APPLICATIONS FOR EVERYDAY DENTISTRY & HYGIENE

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Scott D. Benjamin, D.D.S.

www.DentalAIM.org Education@DentalAIM.org

607-563-3927

The 2 Basic Functions a Laser Can Perform:

1. Heats Up / Vaporizes Material

- Inactivate Bacteria & Microorganisms
- Protein Denaturation
- Ablate (Vaporize or Erase)
- Soft Tissue & Similar Substances
- Incise / Excise Soft Tissue

2. Stimulates a Response

- Photobiomodulation (LLLT, Phototherapy, Photomedicine)
- Stimulates or Inhibits a Physiologic Response
- Photochemical Reaction (Curing Materials, etc.)

Hard Tissue Laser Procedures & Applications:

Partial List of Hard Tissue (Dentition and Osseous) Procedures that a Laser Can Perform or Assist in the Treatment of:

- Caries Removal, Restorative Preparations,
- Enamel Roughing
- Cleaning of Endodontic Canals and Pulpal Chambers
- Osseous Crown Lengthening
- Osseous Shaving, Contouring, and Recontouring (Osteoplasty and Osteotomy)
- Treatment of (Bisphosphonate Related) Osseous Necrosis of the Jaw (BONJ / ONJ)
- Assisting in Bleaching of Dentition
- Removal of Coronal Pulp (Pulpotomy and hemostasis of pulp horns)
- Treatment of a Failing Implant
- Apicoectomy Surgery
- Removal of Composite Restorative Material
- Removal of Porcelain Veneer (and removing cement from a porcelain veneer)
- Removal of Filing Materials During Root Canal Retreatment
- Detection and Removal of Subgingival Calculus

Soft Tissue Procedures & Applications Performed with the Assistance of a Soft Tissue Laser

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A Partial List of Specific Procedures That Can Be Performed with the Assistance of a Soft Tissue Laser

- Gingivectomy
- Gingivoplasty
- Gingival Troughing
- Periodontal Pocket Decontamination Laser Therapy (PDLT)
- Biopsies
- Fibroma Removal
- Implant Uncovering
- Flap Surgery
- Soft Tissue Incisions
- Excising Soft Tissue
- Destruction of Lesions
- Aphthous Ulcer Treatment
- Treatment of Herpetic Lesions
- Treatment of a Venous Lake
- Distal / Proximal Wedge
- Operculectomies
- Excision of Pericoronal Gingiva
- Soft Tissue Crown Lengthening
- Removal of Hyperplastic Tissue
- Pulpotomy as an Adjunct to Root Canal Therapy
- Coagulation of Extraction Sites
- Cementum Mediated New Periodontal Attachment to the Root Surface
- Exposure of Un-erupted Teeth
- Vestibuloplasty / Frenuloplasty
- Frenectomy / Frenotomy
- Incision and Drainage
- Assisting in Bleaching of Dentition
- Prevention & Treatment of Oral Mucositis
- Management of Temporal Mandibular Discomfort
- Stimulate & Enhance Healing
- Reduce Inflammation

Photobiomodulation

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What is Photobiomodulation (PBM)?

Photobiomodulation (PBM) is the use of Low Levels of Light / Laser Energy to produce a chemical response that has a biological effect on the target cells / tissue that are absorbing the light energy.

Photobiomodulation is the application of light energy of narrow spectral width to a pathology to promote tissue regeneration, reduce inflammation and relieve pain. Ideally it is applied to the injury for a minute or so, a few times a week for several weeks. PBM) is not an ablative but rather a photochemical effect comparable to photosynthesis in plants whereby the light is absorbed and exerts a chemical change.

The effects of Photobiomodulation on the target tissue can be either the STIMULATION or INHIBITION of a biologic response.

Usually the wavelength (WL) of the light energy used is in the visible or near infrared (NIR)

Photobiomodulation (PBM) / Photobiomodulation Therapy (PBMT) Definition:

"Light energy (photons) penetrating tissue where it interacts with chromophores located in cells resulting in photophysical and photochemical changes that lead to alterations at the molecular, cellular and tissue levels of the body. PBM and PBMT are accurate and specific terms for this effective and important therapeutic application of light."
http://www.aslms.org/for-the-public/treatments-using-lasers-and-energy-based-devices/photobiomodulation

In the past PBM / PBMT has Been Also Known As (AKA)

- Low Level Laser Therapy (LLLT)
- Low Level Light Therapy (LLLT)
- Low Intensity Laser Therapy
- Soft Laser Therapy
- Cold Laser Therapy
- Laser Therapy
- Phototherapy
- Photomedicine
- Laser Biostimulation
- Laser Inhibition
- and over 70 Other Names…..

Photobiomodulation Research

- Over 30 Studies on PBM are Being Published Every Month
- Approximately 500 Randomized Controlled Trials have Been Performed
- Over 4,000 Laboratory Studies have Been Published

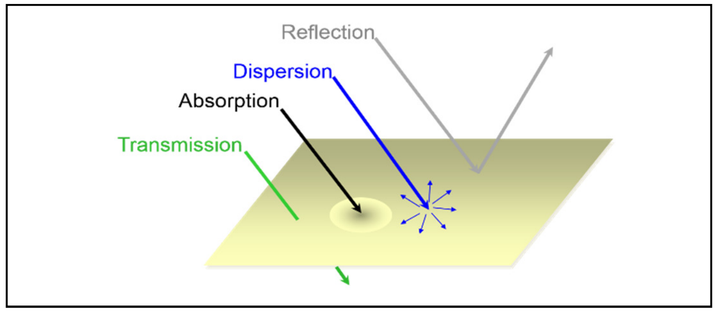
Partial List of Photobiomodulation's Dental / Oral Applications

- Preventing, Managing, and Eliminating Oral Mucositis
- Reducing Inflammation and Edema
- Reducing Peri & Post Operative Pain
- Enhancing Healing and Tissue Repair
- Enhancing Orthodontic Treatment
- Treatment of Herpetic Lesions
- Treatment of Aphthous Ulcers
- Dentinal Desensitization
- Dentin Formation
- Providing Analgesia
- **Treating and Managing**
  - Paresthesia / Nerve Damage
  - Neuropathic Pain
  - Xerostomia
  - ONJ
  - TMJD
  - Trismus
  - Gingivitis
  - Lichen Planus
  - Denture Stomatitis
  - Trigeminal Neuralgia

Effects of Light Energy

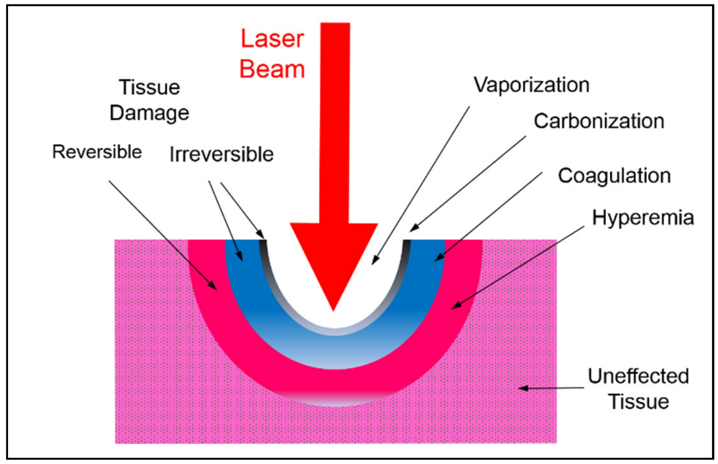
Effects of Light on Target Tissue

- Reflection
- Dispersion / Scattering
- Absorption
- Transmission



Effects of Light Energy on Target Subjects

- Photo-thermal Effects
  - Coagulation
  - Vaporization
- Photo-acoustic Effects
  - Disruption
  - Plasma effect
- Light-Induced Fluorescence
  - Caries detection
  - Mucosal evaluation
- Photo-chemical Effects
  - Stimulate chemical reactions
  - Creates chemical bonds
  - Break chemical bonds
- Photobiomodulation
  - Pain relief
  - Wound healing



Thermal Effect of Laser Energy on Tissue

Tissue Temperature (C°)	Observed Effect
37-50°	Hyperthermia
50-60°	Bacteria Inactivation & Protein Denaturation*
> 60°	Coagulation
70-90°	Welding
100-150°	Vaporization
>200°	Carbonization

*Russell, AD
Lethal Effects of Heat on Bacterial Physiology and Structure
Science Progress, 86:115-137 February 2003

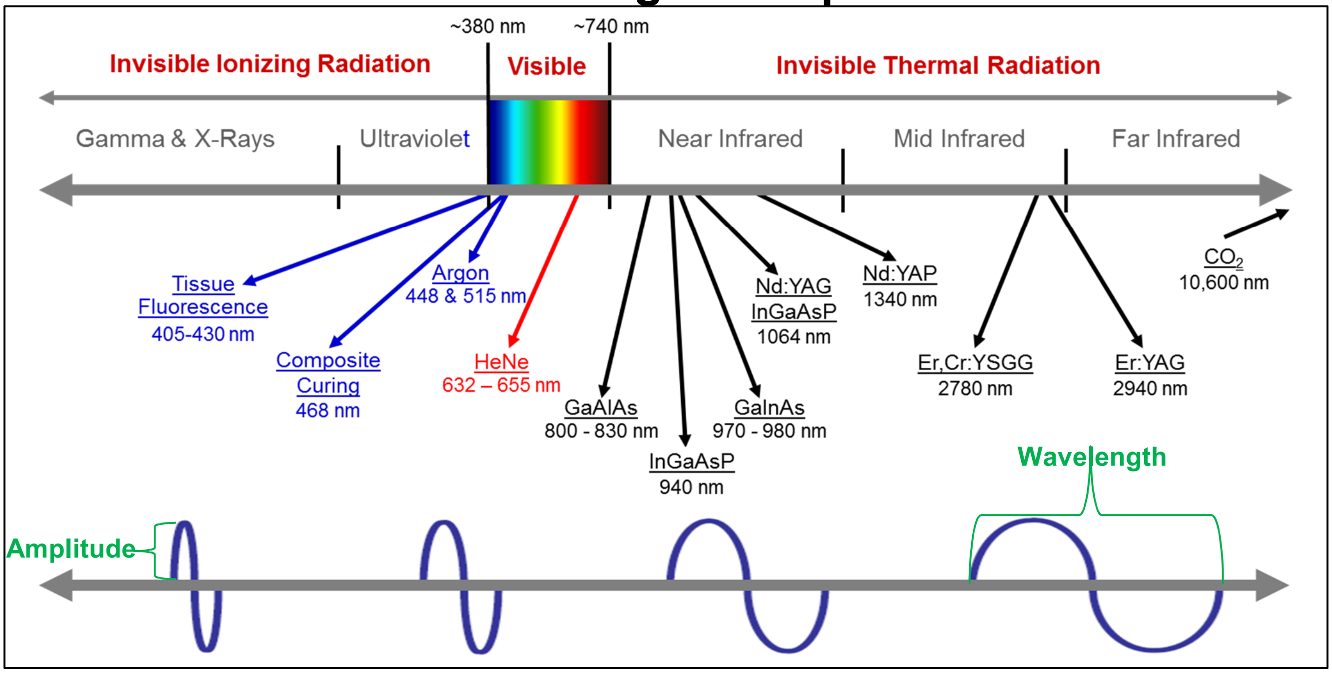
There is a linear relationship between the energy of the pulse and the size of the ablation crater.
Increasing the power lowers the ablation threshold and accelerates the ablation process, thus decreasing thermal side effects.

Variables Effecting Laser Tissue Interaction

- Wavelength
- Target Composition
  - Chromophores- Substances that absorbs light energy
  - Fluorophores- - Substances that emits (produces) light, often when stimulated with light energy
- Interaction Time
  - Temporal Mode
  - Hand Speed
  - Total Interaction Time
- Power
- Energy Transfer Mode
  - Contact vs. Non-Contact
- Spot Size
  - Fiber size (320 micron vs. 200 micron diameter fiber)
- Operator's Knowledge and Experience

Maximizing the Tissue Interaction Requires:
Tissue interaction is maximized by matching the proper wavelength with the adequate amount of power with the chromophores present in the tissue.

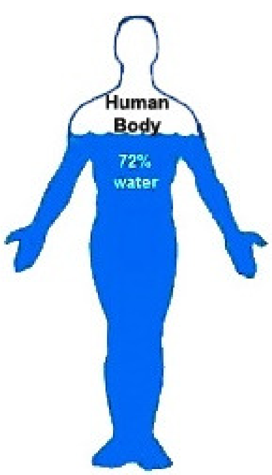
Wavelengths of Light Energy Used in Dentistry on the Electromagnetic Spectrum



Active Mediums & Wavelengths of Surgical Dental Lasers

Active Medium	Wavelengths
▪ Argon	448-515 nm
▪ Diodes	445-1064 nm
• InGaN	445 nm
• HeNe	630-665 nm
• GaAlAs	805-830 nm
• InGaAsP	940 nm
• GaInAs	970-980 nm
• InGaAsP	1064 nm
▪ Nd:YAG	1064 nm
▪ Nd:YAP	1340 nm
▪ Erbium,Cr:YSGG	2780 nm
▪ Erbium:YAG	2940 nm
▪ CO_2	9,250-10,600 nm

Water Content By Percentage (%) in Biological Components



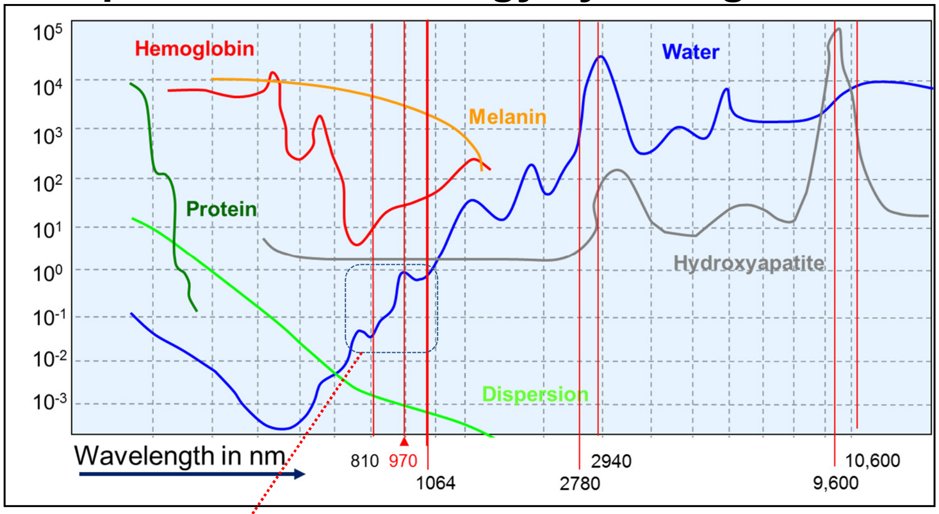
- **Blood ~94%**
- **Mucosa ~75%**
- **Muscle ~75%**
- **Skin ~70%**
- **Bone ~22%**
- **Dentin ~12%**
- **Enamel ~1-3%**

Source: http://www.waterinfo.org/resources/water-facts

- **Bacteria ~92%**

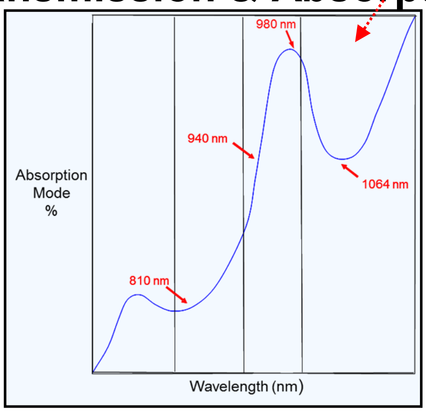
Relationships between the Cell Volume and the Carbon Content of Bacteria
Romanova ND, Sazfin AF
Oceanology 2010, Vol,50 No. 4 pp 522-530

Absorption of Laser Energy by Biological Tissue



Source: Hale GM, Querry MR, "*Optical constants of water in the 200 nm to 200 µm wavelength region*" Appl. Opt.,12, 555-563

Transmission & Absorption of Near Infrared (NIR) Light Energy in Water



The Absorption of Light Energy in Water is:

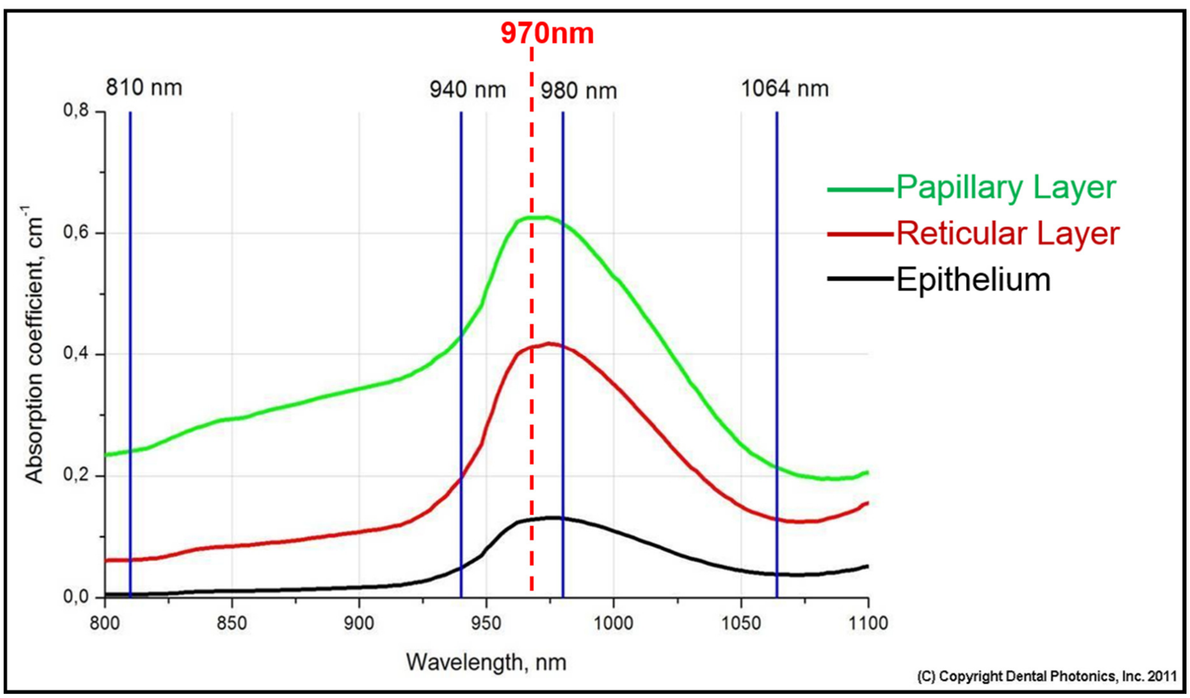
- **35% at 980 nm**
- **15% at 1064 nm**
- **3% at 810 nm**

The Coefficient of Light Transmission in Water is:

- **97 % at 810 nm**
- **85 % at 1064 nm**
- **65 % at 980 nm**

Cecchetti W, Guazzieri C, Tasca A, Dal Bianco M, Zattoni F, Pagano F
980 nm Diode Laser and Fiber Optic Resectoscope in Endourological Surgery
European Biomedical Optics Week, BiOS Europe '96

Light Absorption of Mucosa for the Near Infrared (NIR) Laser Range

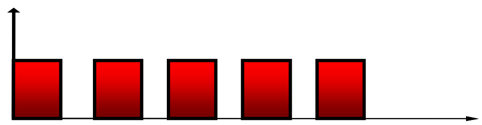


Source: Feldchtein F; *Soft Tissue Surgery with Diode Laser - Direct Laser Cutting or Hot Tip?*
Presented at the 18th Annual Conference of the Academy of Laser Dentistry; San Diego, CA; March 3, 2011

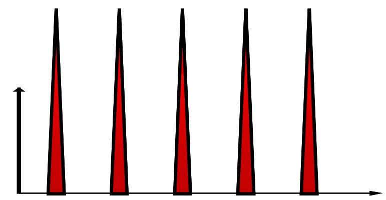
Temporal Emission Modes

Temporal Emission Mode assists in managing the tissue interaction by controlling the amount of time that laser energy interacts with the tissue, by allowing or not allowing time for the remaining tissue to cool between the pulses of energy emitted by the laser. The 3 basic temporal emission modes used in dentistry are Continuous Wave (CW), Pulse (Chopped), and Free Running Pulse. All the other terms used are variations of the Pulse mode. All diode lasers only have the option of using either a Continuous Wave (CW) or Pulse (Chopped) emission mode.

Continuous Wave (CW)



Pulse (Chopped)



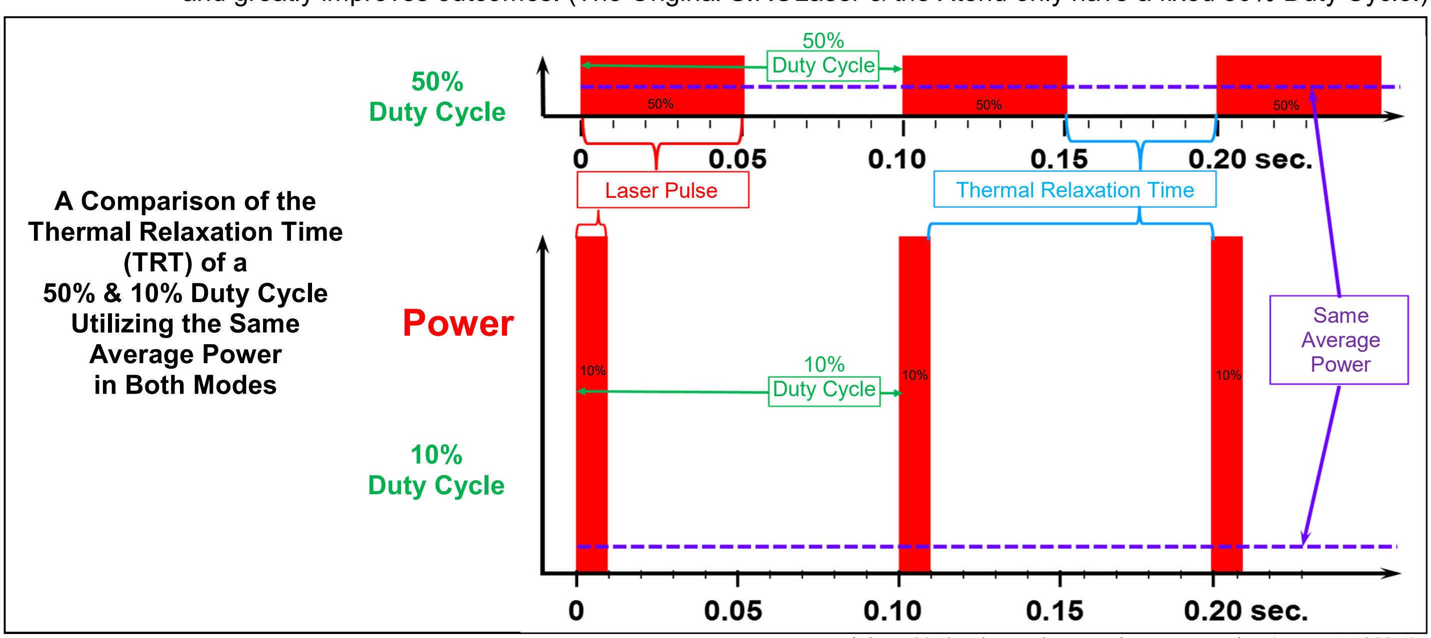
Free Running Pulse

Thermal Relaxation Time (TRT) - The time when the laser energy is not being emitted (off). The purpose of the thermal relaxation time (TRT) is to give the surrounding tissue (the non target tissue) time to cool between the pulses of laser energy thus assists in minimizing the thermal transmission into the collateral tissue. This helps to minimize the collateral damage to the remaining tissue and reduces the zones of thermal necrosis and hyperemia (inflammation). Basically, the longer the TRT the more tissue cooling that occurs and the less collateral damage to the remaining tissue.

- **Continuous Wave (CW) Mode - Does NOT allow for any Thermal Relaxation Time (TRT)**
  - CW has the greatest amount of collateral damage and creates the largest zones of thermal necrosis and thermal conduction and therefore has the greatest amount of coagulation.
- **Pulse (Chopped) Mode - Does allow for Thermal Relaxation Time (TRT)**
  - **It creates considerably less thermal damage when compared to Continuous Wave (CW).**
  - When used in a pulse mode it can help minimize the zones of thermal necrosis and thermal damage.
  - The high powered 970 nm SIROLaser in the peak pulse (PP) frequency mode provides the ability to control the Thermal Relaxation Time (TRT) by automatically adjusting the Duty Cycle when the average power is changed by the clinician to obtain the desired results.
  - Additionally the ability of the SIROLaser to use water or a liquid for convection cooling can further reduce the collateral heat spread & damage especially when used in the Pulse (Chopped) or Peak Pulse (PP) mode.
- **Free Running Pulse Mode** -Provide a long and excellent Thermal Relaxation Time (TRT), however, a free-running pulse mode is not available on any diode laser.

Duty Cycle (Emission Cycle) –The temporal duty cycle (sometimes referred to as an emission cycle) is the percentage (%) of time that the laser is Emitting Laser Energy vs. the Thermal Relaxation Time (TRT) within a single pulse. Simply put, it is the percentage of time the laser is on vs. off per pulse cycle.

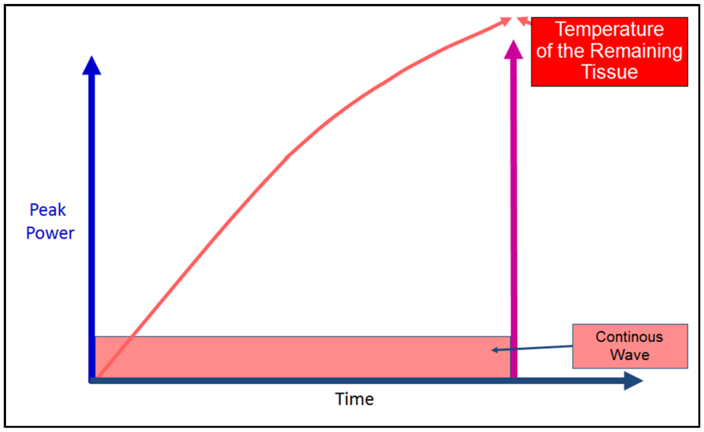
- **The SIROLaser Advance laser allows the clinician to adjust the duty cycle (the percentage (%) of time that the energy is being emitted) from 1 to 100% of the emission or pulse cycle.**
  - This allows for maximum control of the Thermal Relaxation Time (TRT) by extending the TRT as long as desired or even completely eliminating it. This enables the ideal treatment objective to be accomplished and greatly improves outcomes. (The Original SIROLaser & the Xtend only have a fixed 50% Duty Cycle.)



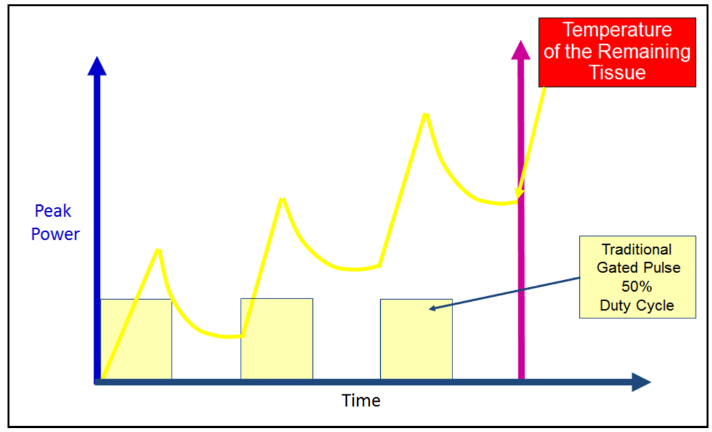
Temporal Emission Modes

(Continued)

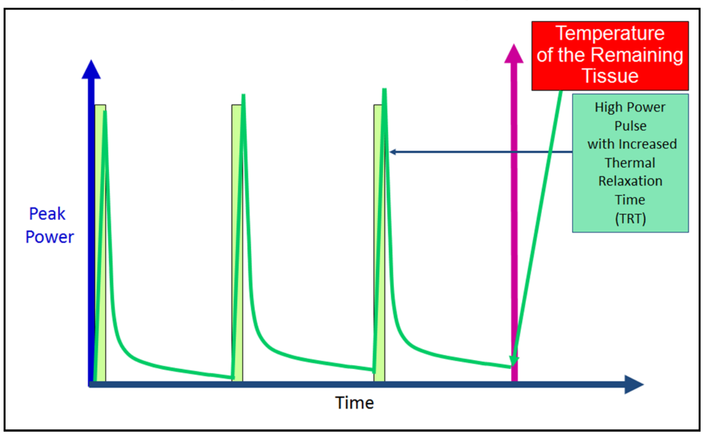
Continues Wave Temporal Mode
Note the Continuous Rise in Remaining Tissue Temperature
(Solid Red Line)



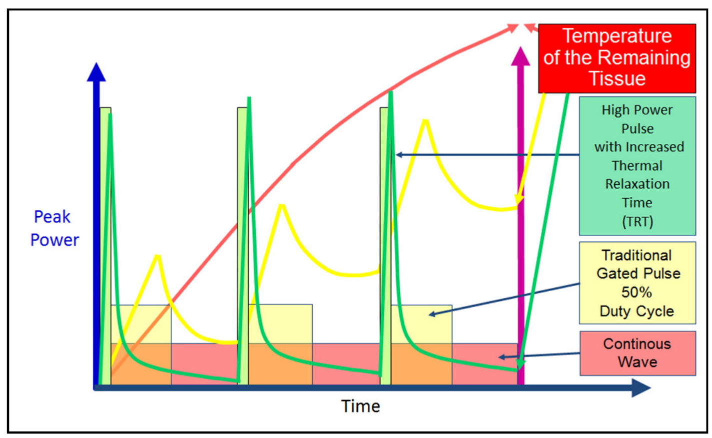
Pulsed (Chopped) Temporal Mode 50% Duty Cycle
Note the Rise & Fall in Remaining Tissue Temperature
(Zig-Zag Yellow Line)



Pulsed (Chopped) Temporal Mode 10% Duty Cycle
Note the Minimal Rise in Remaining Tissue Temperature
(Zig-Zag Green Line)



Comparison of Different Temporal Modes
Note the Differences in Remaining Tissue Temperatures
Between Red – Yellow – Green Lines



Comparison of Different Temporal Pulse Modes and Duty / Emission Cycle Effects on Coagulation

Free Running Pulse or Pulsed (Chopped) 10% Duty Cycle	Pulsed (Chopped)) 25% Duty Cycle	Pulsed (Chopped) 50% Duty Cycle	Pulsed (Chopped) 75% Duty Cycle	Continuous Wave CW=100% Duty Cycle

Minimal Coagulation ⟷ **Maximum Coagulation**

Least Amount of Collateral Thermal Damage ⟷ **Most Amount of Collateral Thermal Damage**

Continuous Wave (CW) Mode Will Provide
Maximum Coagulation and Cause the Most Thermal Damage

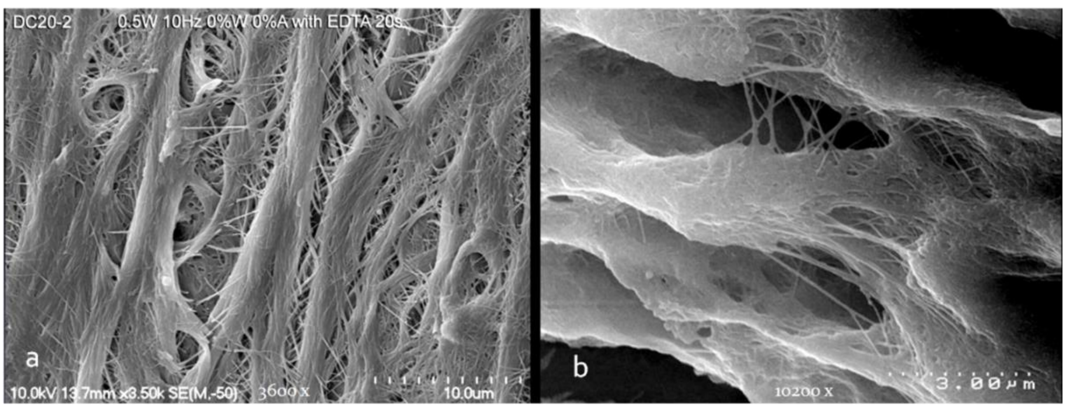
Overview

Photon-Induced Photoacoustic Streaming (PIPS®) & Shock Wave Enhanced Emission Photoacoustic Streaming (SWEEPS) Utilizing the LightWalker Er:YAG Laser in Root Canal Therapy

Use of the Photon-Induced Photoacoustic Streaming (PIPS) and Shock Wave Enhanced Emission Photoacoustic Streaming (SWEEPS) protocols enables the 3-dimensional cleaning and disinfection of the entire root canal system. They enable the removal of the smear layer after root canal instrumentation thus permitting the complete obturation of the entire root canal system including lateral / accessory canals and the anastomoses between the all of the canals.

Presently these techniques can only be accomplished the use of LightWalker® Er:YAG laser due to its ability to produce a very short 50 microsecond (µsec) pulses and unique pulse configurations. The protocol also requires the use of specially designed tips to produce the desired photon induced action to remove the organic materials from the entire root canal system.

The protocols are very specific and involves the use of a series of irrigation techniques with water, Sodium Hypochlorite (NaOCl), and Ethylene Diamine Tetra Acetic acid (EDTA) while applying photonic laser energy in 50 µsec pulse increments for several delivery cycles. The goal is to dissolve and remove all of the organic materials from the entire root canal system to help facilitate sealing the complete system to prevent reinfection.



SEM of the Endodontic Canals After Treatment with the PIPS® Protocol and the LightWalker® Er:YAG Laser
Images Courtesy of Dr. Enrico DiVito, Scottsdale, AZ.

Due to minimal removal of the hard structures and the very fine constrictions of the systems architecture, lateral / accessory canals, and the anastomoses between the canals that have been thoroughly cleaned and disinfected with this technique the canals must be obturated with a very thin bio-compatible material / sealer such as Ultradent's EndoRez. Conventional obturation techniques can additionally be performed to compliment the procedure if so desired.

To utilize the PIPS and SWEEPS protocols and acquire the specialized tips required to perform the technique, clinicians are required to attend a recognized detailed training program on the techniques. The goal is to gain a thorough and comprehensive knowledge of the protocol and to help insure successful outcomes.

Laser Assisted Periodontal Care
Pocket Decontamination Laser Therapy (PDLT)

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Overview

When utilizing a laser in periodontal care the principles of the causes, treatment, historical goals, and management of periodontal disease, do not change. The primary goals in the treatment of periodontal disease are to:

- Decontaminate the periodontal pocket and the infected tissue of the periodontal pocket
- Arrest the progressive destruction of periodontal attachment.
- Create an environment to facilitate the regeneration of the lost periodontium, whenever possible.
- Establish a periodontal architecture that can be properly maintained with adequate home care.

One of the most valuable functions of the correct laser in periodontal care is to assist in the initial non-surgical management of periodontal disease. The laser assists in decreasing the bacterial load and assists in the decontamination of the diseased sulcular epithelium. When this is accomplished, pocket depths are normally reduced and the condition of the periodontium is able to be maintained with proper routine homecare. Bleeding on probing should be eliminated, the apical migration of the epithelial attachment halted, and most often there is a gain in the clinical attachment of the soft tissue to the root structure of the tooth.

Treatment Considerations

Comprehensive examination and diagnostic procedures need to be performed to establish an accurate diagnosis of the periodontal status. Prudent clinical judgment is always required and the practitioner and the patient need to have realistic expectations for the desired outcomes. Informed consent from the patient on the treatment objectives, prognosis and possibility of tooth loss should be established before any treatment is rendered.

The Role of the Laser as an Adjunctive Modality to Scaling and Root Planing

A soft tissue laser and is an adjunctive device primarily used in closed subgingival instrumentation procedures without the displacement (flapping) of the gingiva. The laser's role is not to replace any of the traditional procedures or instrumentation, but is used in addition to ultrasonic and hand instrumentation to obtain a better outcome. The laser's primary role is to reduce as much as possible the bacteria in the periodontal pocket and to assist in creating an enhanced environment to help facilitate the reattachment of the soft tissue to the root structure of the tooth. All clinicians must only perform lasers procedures that are permitted within their scope of practice that is defined by the Provincial or State's Dental and Dental Hygiene Practice Act. Laser decontamination is accomplished by the clinician thoroughly applying photonic energy to the entire soft tissue lining of the periodontal pocket. A Nd:YAG laser with a 1064nm wavelength with an extremely high peak power (~1,000 watts) and extremely short pulse durations of 100 to 650 microseconds is an ideal modality to accomplish this goal.

The composition of bacteria being approximately 90% water. This enables a diode laser with the 970nm wavelength which has a significantly higher absorption of laser energy in water when compared to other diode lasers is another ideal treatment modality to inactivate the bacteria in the periodontal pocket. This also requires a high peak power and very short pulse width.

The short pulse width (or duty cycle) plays a significant role in minimizing collateral tissue damage while creating the proper environment for the establishment and organization of a sufficient and stable clot to promote healing to naturally occur. Commencing and maintaining this healing process is imperative in the re-establishment of the periodontal attachment architecture to the root structure of the tooth, thus minimizing pocket depths and to arresting the apical migration of the attachment. Additionally, the appropriate laser wavelength can assist in removal of diseased, inflamed, or inappropriate soft tissue in the periodontal pocket by the appropriate clinician.

Practitioners need to have a comprehensive understanding of the disease processes, the benefits and limitations of laser's decontamination ability, as well as, the present periodontal status of the patient and the patient's overall oral and systemic health. The clinician and patient need to understand and remember that reduction of the pathologic materials and periodontal pocket decontamination are only part of the comprehensive treatment regime, and that ongoing care is required to achieve long term successful outcomes.