LASER THERAPY: Applying What We Know

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Objectives

* Explain How Lasers work
* Review differences between various lasers: wavelengths, absorption, scatter
* Describe mechanism of action of lasers in tissue
* Illustrate examples of laser's benefits as found in the literature and clinical settings

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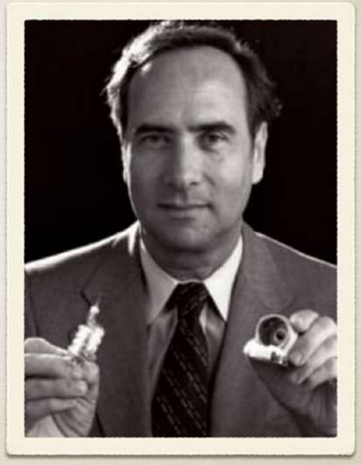
Introduction

- Where was first laser developed?
- When was first laser developed?
- California, USA
- 1960 - ruby laser



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History of Laser Therapy

- Endre Mester (Budapest, Hungary) - Father of Low Level Laser Therapy
- 1967 Experiment:
  - Could laser be used to treat cancerous tumors?
  - Used low power ruby laser (694 nm)
  - Laser treatment did NOT kill cancer cells
  - Laser treatments DID enhance healing of incisions and hair growth.
  - First to observe photobiomodulation (PBM)

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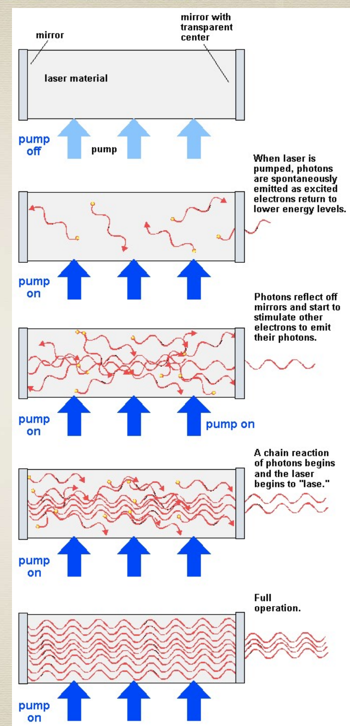
What Is LASER?

- L.A.S.E.R. (acronym) - Light Application by Stimulated Emission of Radiation
- In other words, it is a device capable of converting light or electrical energy into a focused, high energy beam.
- Laser light is monochromatic (contains a single light frequency) and doesn't spread out much over long distances.



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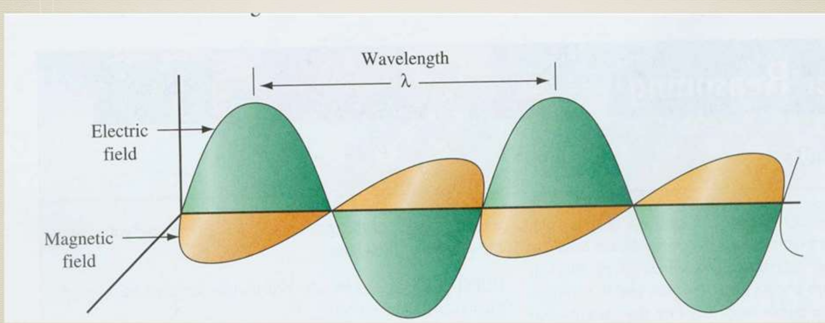
Laser Basics



Photons - Electromagnetic Characteristics

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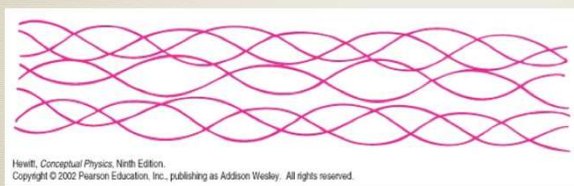
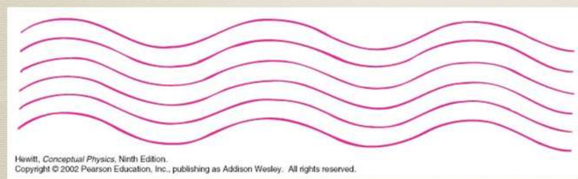
Laser Basics

* Non-coherent, non-monochromatic photons (white light or lamp)



* Non-coherent, monochromatic photons (LED)



* Coherent, monochromatic photons (Laser)

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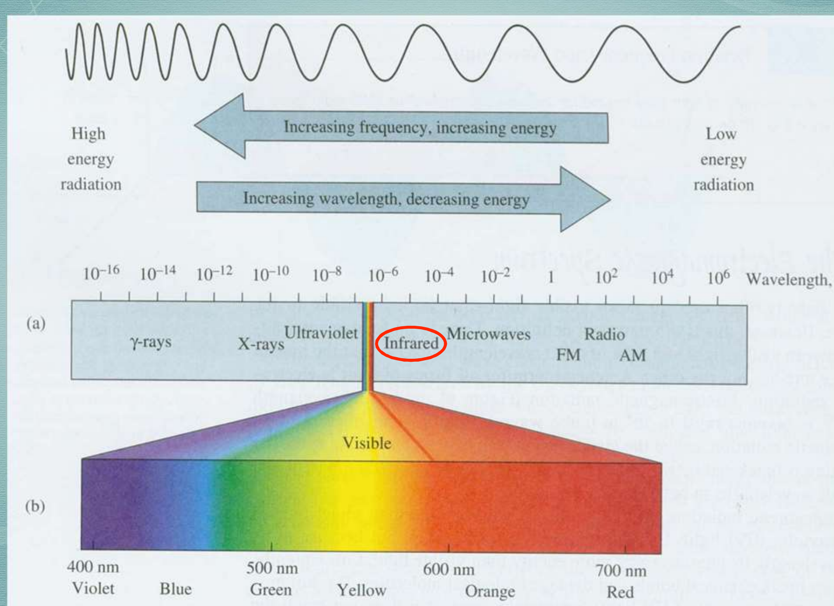
Electromagnetic Spectrum



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TWO KEY PRINCIPLES

Laser Therapy: Clinical Practice and Scientific Background. (Prima Books, 2003)
by Jan Tuner and Larse Hode:

* **Photons must reach the target tissue.** Therefore, anatomical and histological factors must be taken into account (tissue composition, depth & paths)
* **Target tissue/organ must absorb the photons at the cellular level.** Therefore, proper wavelength, laser power and photon density must be used

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Anatomical Considerations: Shoulder

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Anatomical Considerations: Shoulder

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Laser Basics: Absorption

- When the light strikes the biological tissue, part of it is absorbed, part is reflected or scattered, and part is further transmitted.
- Scattering behavior of biological tissue is important because it determines the volume distribution of light intensity in the tissue. This is the primary step for tissue interaction, followed by absorption.

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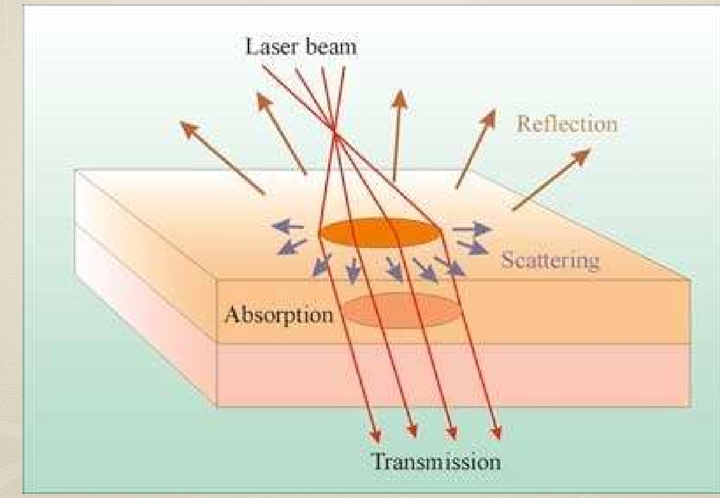
Laser-Tissue Interactions



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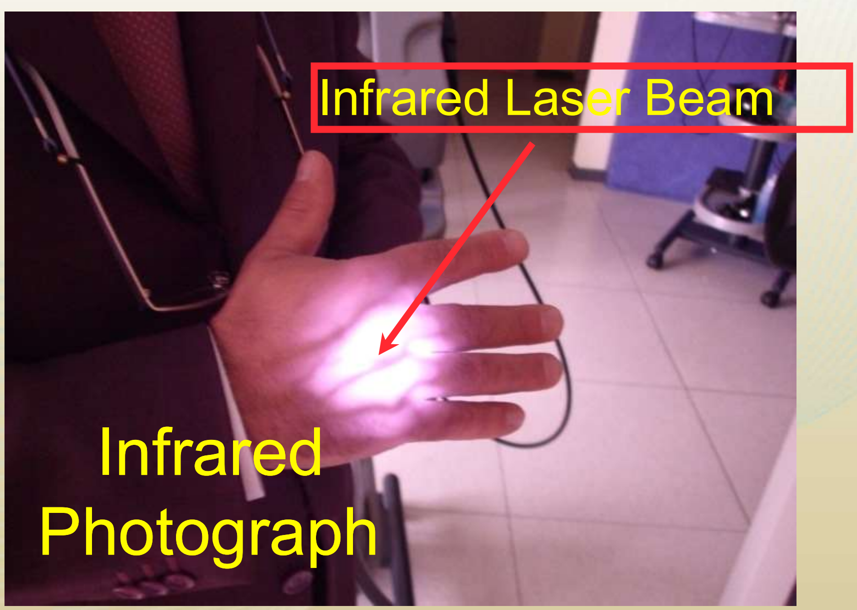
Tissue Penetration



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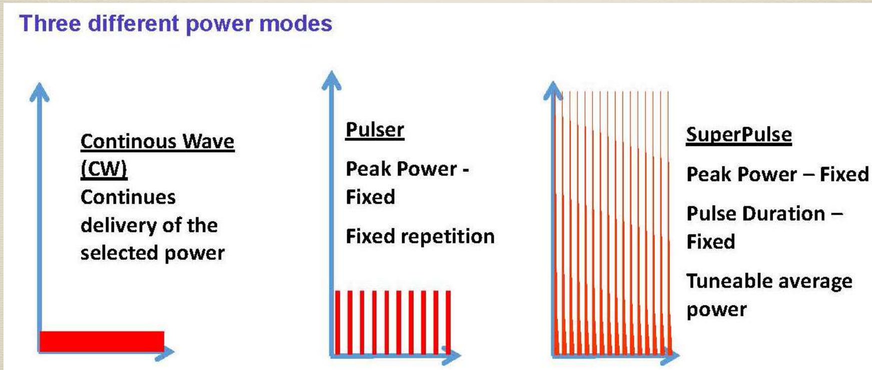
Laser Basics: CW vs Superpulsed



- Continuous wave
- Gated pulsed - *500 thousandth* of a sec
- Superpulsed - **200 billionth of a sec**

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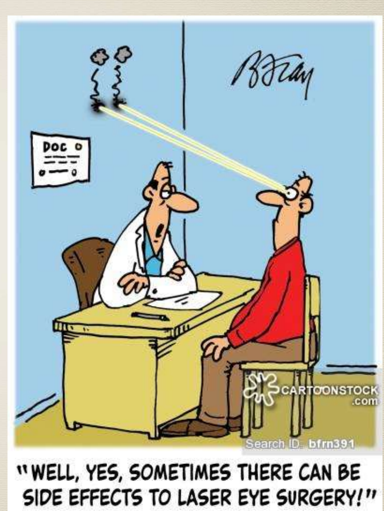
Laser Basics: Superpulsed Laser

- 5 advantages of Super Pulsed Laser:
  - More Power
  - Increases in **peak power**
  - Breakthrough in thermal barrier
  - Maximum photonic density - power density during these very high pulses yields an extremely high photon flux and saturation, further delivering stronger therapeutic effect into tissue and ↑ ATP production
  - Safety - no thermal damage



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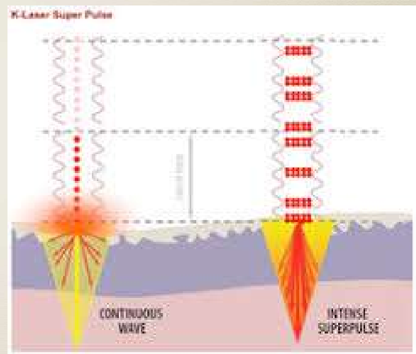
Laser Basics: Superpulsed Laser

- Pig Craniums: Pulsed light administered to pig craniums → no significant change in temp of the scalp or skull tissue. *Anders et al.*
- CW caused marked neurological deficits in pigs, while PW did not (at equal power density).



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Laser Basics: Penetration

- Dependent on peak and average power output mostly and <u>minimally</u> on the treatment time
- Longer wavelengths penetrate further (physics of photonics)
- Depth of penetration is an inverse square relationship
- High <u>average</u> power leads to thermal risks
- High <u>peak powers</u> do not produce thermal effects

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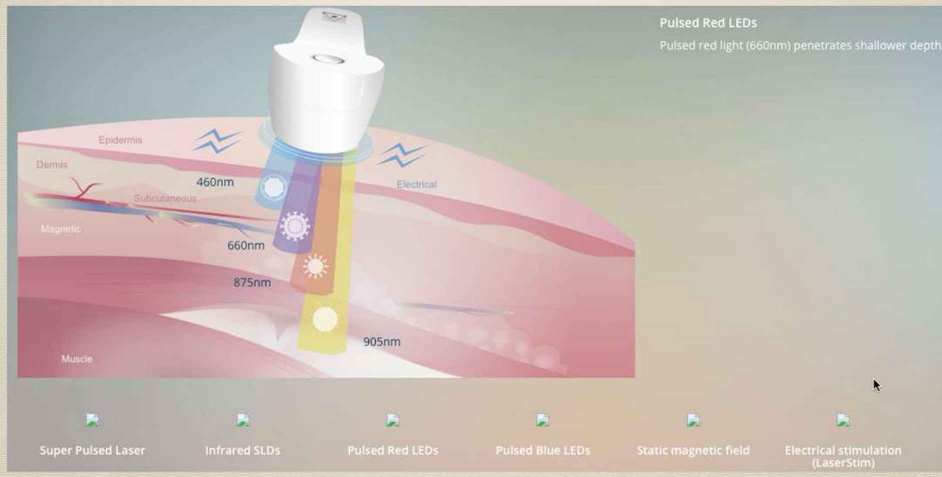
Laser Basics: Penetration



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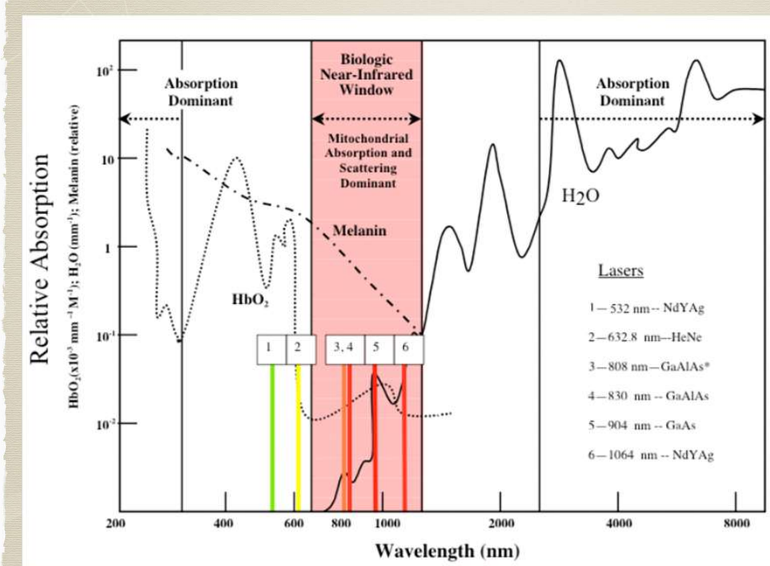
Laser Basics: Therapeutic Window



Wavelengths:

- **600–700 nm (0.5-1cm for superficial tissue)**
- **780–950 nm (2-5 cm to treat deeper tissues)**
- **970-990 nm (1-2cm)**
- **990-1200 nm (4-5 cm)**

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Low Level Laser Therapy (LLLT)/Photobiomodulation (PBM)

- These treatments were originally referred to as "low level laser" because the light is of low intensity compared with other forms of medical laser treatment, which are used for ablation, cutting, and coagulation.
- 2014 - **Photobiomodulation (PBM)** was accepted as the preferred name.

"The therapeutic use of light (e.g. visible, near infrared (NIR), infrared (IR)) absorbed by endogenous chromophores, triggering non-thermal, non-cytotoxic biological reactions through photochemical or photo physical events, leading to physiological changes."

2014 Joint North American Assoc of Laser Therapy and World Assoc for Laser Therapy Conference

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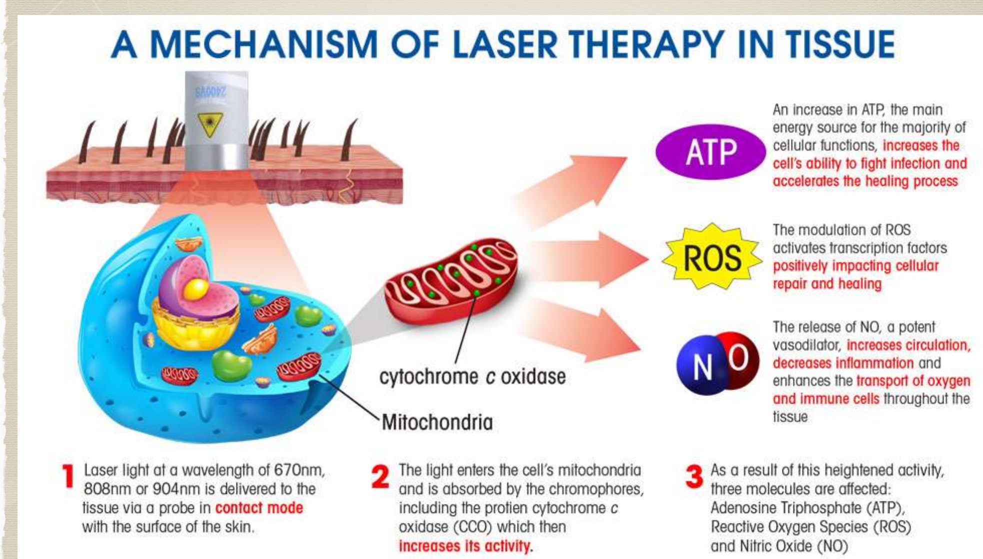
LLLT/PBM: Mechanism of Action



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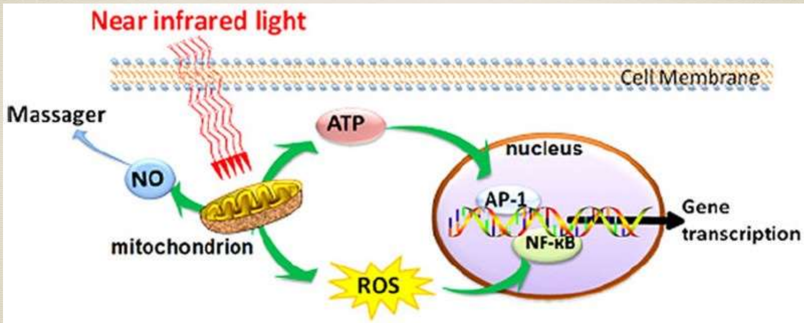
LLLT/PBM: Mechanism of Action



- Cellular mechanisms of LLLT. Schematic diagram showing the absorption of red or near infrared (NIR) light by specific cellular chromophores or photoacceptors localized in the mitochondrial. During this process in mitochondria respiration chain ATP production will increase, and reactive oxygen species (ROS) are generated; nitric oxide is released or generated. These cytosolic responses may in turn induce transcriptional changes via activation of transcription factors (e.g., NF-κB and AP1).

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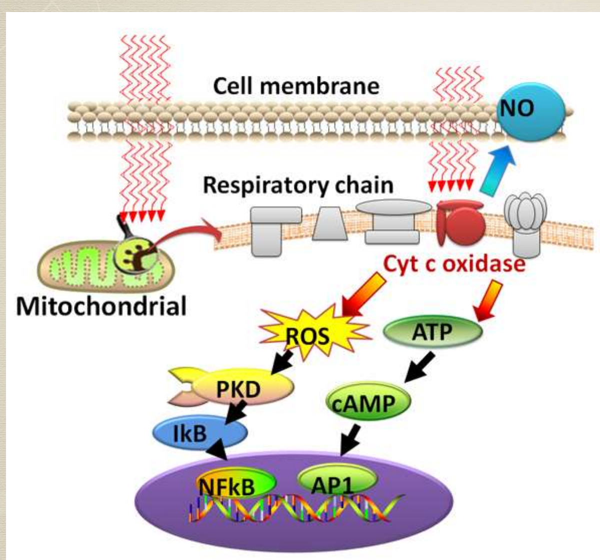
LLLT/PBM: Mechanism of Action



- Current data suggest that PBM acts predominantly on cytochrome c oxidase (CcO) in the mitochondrial respiratory chain by facilitating electron transport resulting in an increased transmembrane proton gradient that drives adenosine triphosphate (ATP) production
- In hypoxic or otherwise stressed cells, mitochondria produce nitric oxide (mtNO), which binds to CcO and displaces oxygen. This binding results in inhibition of cellular respiration, decreased ATP production, and increased oxidative stress —> increased production of inflammatory mediators (TNF-α,IL-1, IL-6 and COX-2)
- Evidence suggests that when PBM is administered with appropriate parameters to stressed cells, NO is dissociated from its competitive binding to CcO, ATP production is increased, and the balance between prooxidant and antioxidant mediators is restored, resulting in reduction of oxidative stress.

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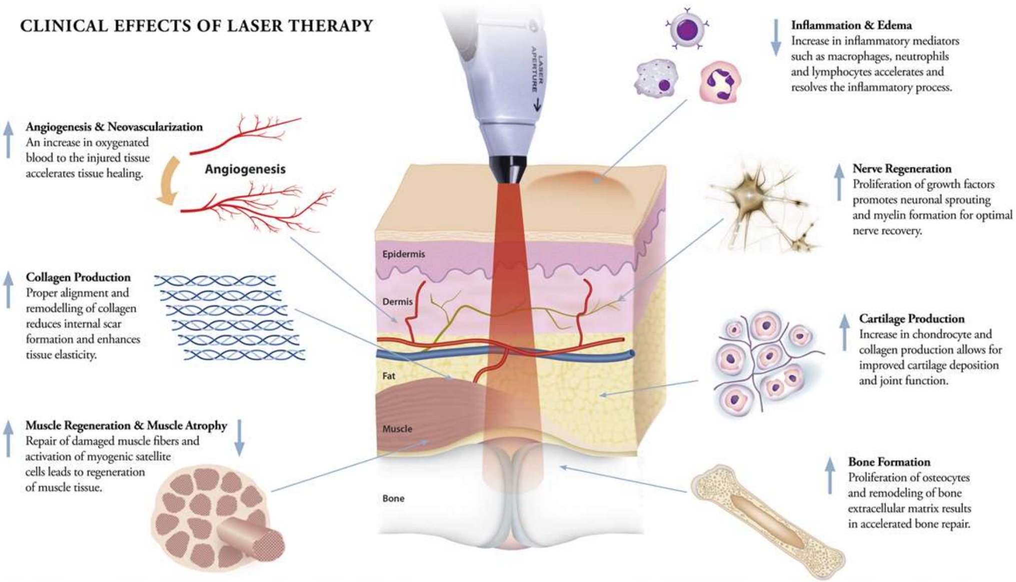
LLLT/PBM: Mechanism of Action



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LLLT/PBM: Ischemic Stroke

Transcranial near infrared laser treatment (NILT) increases cortical adenosine-5′-triphosphate (ATP) content following embolic strokes in rabbits

BRAIN RESEARCH

- The original rabbit embolic stroke study by Lapchak et al, showed that 10 minute irradiation of the rabbit brain at midline at a wavelength of 808 nm can produce significant behavioral improvement in small-clot embolized rabbits, when administered either as a continuous wave (CW) or a pulsed wave (PW). CW caused 3 degree temp change.
- He wanted to demonstrate effects of PBM at cellular level.
- Embolization of rabbits resulted in **46% decrease** in cortical ATP.
- CW increased ATP by **41%** (almost back to baseline).

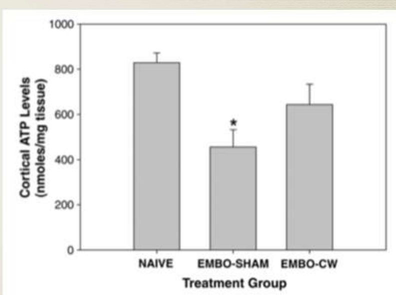

Fig. 1 – Effects of embolization and CW NILT on cortical ATP content. Embolization (EMBO-SHAM) resulted in a 46% decrease of cortical ATP (*$p<0.05$) compared to NAÏVE control rabbits, a decrease that was attenuated (41% increase) by CW NILT (EMBO-CW). There was no significant difference between the EMBO-CW group and either the EMBO-SHAM or the NAÏVE control group using an $n=8$ per group ($p=0.1357$ and 0.0826, respectively).

BRAIN RESEARCH 1306 (2010) 100–105

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LLLT/PBM: Ischemic Stroke

Transcranial near infrared laser treatment (NILT) increases cortical adenosine-5′-triphosphate (ATP) content following embolic strokes in rabbits

BRAIN RESEARCH

- PW increased ATP by **157%** and **221%**, when 5x and 25x more energy than CW was delivered, respectively ($p < 0.05$).

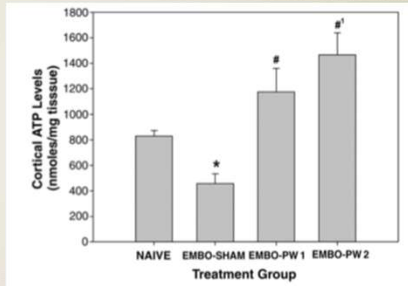

Fig. 2 – Effects of PW NILT on cortical ATP content. Cortical ATP content in the EMBO-SHAM group cortex was significantly decreased compared to the NAIVE control group (*$p < 0.05$). PW NILT (EMBO-PW1 and EMBO-PW2), significantly (#$p < 0.05$) increased cortical ATP content compared to EMBO-SHAM. The EMBO-PW2 ATP content was also significantly different (†$p < 0.05$) from that measured in naive control rabbits ($n = 8$ per group).

BRAIN RESEARCH 1306 (2010) 100–105

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NECK PAIN

THE LANCET

Efficacy of low-level laser therapy in the management of neck pain: a systematic review and meta-analysis of randomised placebo or active-treatment controlled trials

Lancet 2009; 374: 1897–908

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LLLT/PBM: Neck Pain Meta-Analysis

- 16 randomized controlled trials including a total of 820 pts.
- Results showed moderate statistical evidence for efficacy in tx of acute and chronic neck pain.
- In *chronic* neck pain, there was an average reduction in VAS scale of **19.86** (0-100) across all studies (clinically important change).
- Effects lasted up to 3 months after treatment (similar duration to trials for OA, tendinopathies, LBP)
- Used Jadad criteria:
  - Randomization, double-blind design, and description (1 pt for each)
  - Trials with score of 3 or more = high quality

THE LANCET

Lancet 2009; 374: 1897–908

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LLLT/PBM: Neck Pain

THE LANCET

Lancet 2009; 374: 1897–908

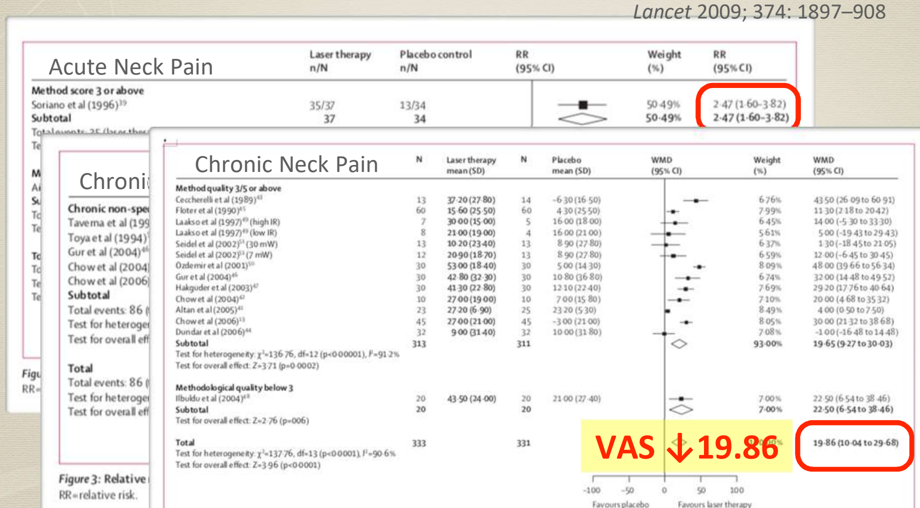

Figure 4: Weighted mean difference in chronic pain reduction on 100 mm visual analogue scale between laser-treated and placebo-treated groups from 11 randomised trials grouped according to Jadad criteria
WMD= weighted mean difference. IR=infrared.

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LLLT/PBM: Neck Pain

Lancet 2009; 374: 1897–908
THE LANCET

- Distance from skin to facet = 1.5-3 cm (without pressure). Since 830 nm and 904 nm lasers penetrate to several cm, anti-inflammatory effects at zygapophyseal joints is likely.
- Inhibition of transmission at NMJ also likely.

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NEURALGIAS/PHN

Effect of Repeated Irradiation of Low-Power He–Ne Laser in Pain Relief from Postherpetic Neuralgia

The Clinical Journal of Pain
5:271–274 © 1989 Raven Press, Ltd., New York

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LLLT/PBM: Neuralgias

- Clinical studies have revealed an increase in nerve function and improved capacity for myelin production
- LLLT has also been shown to be effective for **promoting axonal growth** in injured nerves in animal models
- Multiple studies reveal benefit when used for **PHN or TN**
- In animal models PBM demonstrates improvement of **allodynia** as well as both **nerve regeneration** and **improved motor recovery** after nerve crush injury
- In humans, two small, sham-controlled studies demonstrated that PBM reduced weekly pain scores among pts with diabetic sensorimotor polyneuropathy and improved carpal tunnel syndrome-related numbness and tingling

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Effect of Repeated Irradiation of Low-Power He–Ne Laser in Pain Relief from Postherpetic Neuralgia

The Clinical Journal of Pain
5:271–274 © 1989 Raven Press, Ltd., New York

TABLE 1. *Clinical cases of PHN*

No. of patients	36 cases
Male/female	24/12
Age	63.3 ± 11.5 years
Duration of neuralgia before treatment	30.8 ± 20.4 months
Sites of herpes zoster lesion	
Trigeminal	
I	7 cases (19.4%)
II	4 cases (11.1%)
III	2 cases (5.5%)
Cervical	5 cases (13.9%)
Thoracic	14 cases (38.9%)
Lumbar	4 cases (11.1%)
Sacral	0 cases

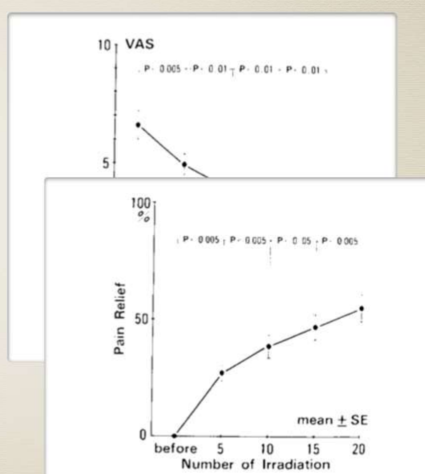

FIG. 3. Pain relief after repeated irradiation.

- Wavelength - 632.8 nm
- Duration ~18.5 min
- 20 sessions

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NEURALGIAS/CIPN

The effect of photobiomodulation on chemotherapy-induced peripheral neuropathy: A randomized, sham-controlled clinical trial

Peter A. Argenta, MD[a,*], Karla V. Ballman, PhD[b], Melissa A. Geller, MD[a], Linda F. Carson, MD[a], Rahel Ghebre, MD[a], Sally A. Mullany, MD[a], Deanna G.K. Teoh, MD[a], Boris J.N. Winterhoff, MD[a], Colleen L. Rivard, MD[a], Britt K. Erickson, MD[a]

P.A. Argenta et al. / Gynecologic Oncology 144 (2017) 159–166

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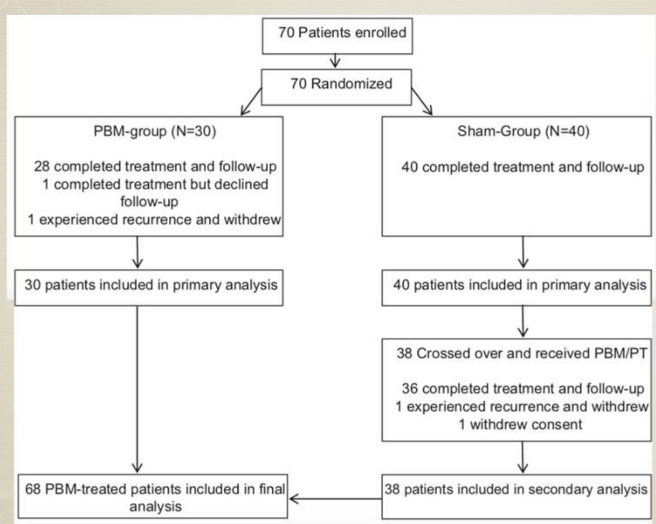
LLLT/PBM: CIPN



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- 70 pts enrolled
- 3 groups: Sham, PBM, PBM + PT

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Table 2
Patient characteristics.

Characteristics	PBM-group	Sham-group	Total
Age (years)			
≤50	2 (6.7%)	2 (5.0%)	4 (5.7%)
51–60	7 (23.3%)	10 (25.0%)	17 (24.3%)
61–70	14 (46.7%)	18 (45.0%)	32 (45.7%)
71–80	7 (23.3%)	9 (22.5%)	16 (22.8%)
>80	0	1 (2.5%)	1 (1.4%)
Gender			
Female	30 (100%)	40 (100%)	70 (100%)
Race			
White	29 (96.7%)	38 (95.0%)	67 (95.7%)
Black	0	1 (2.5%)	1 (1.4%)
Asian	1 (3.3%)	0	1 (1.4%)
Native American	0	1 (2.5%)	1 (1.4%)
Cancer diagnosis			
Gynecologic	21 (70%)	26 (65%)	
Ovarian	19 (63.3%)	15 (37.5%)	34 (48.6%)
Uterine	2 (6.7%)	9 (22.5%)	11 (15.7%)
Cervical	0	2 (5.0%)	2 (2.9%)
Breast	4 (13.3%)	6 (15.0%)	9 (14.3%)
Hematologic	3 (10.0%)	1 (2.5%)	4 (5.7%)
Colon	0	5 (12.5%)	5 (7.1%)
Other	2 (6.7%)	2 (5.0%)	4 (5.7%)
Exposure			
Taxane			
Yes	24 (82.8%)	30 (75.0%)	54 (78.3%)
No	5 (17.2%)	10 (25.0%)	15 (21.7%)
Unknown	1	0	1
Platinum			
Yes	24 (85.7%)	35 (87.5%)	59 (86.8%)
No	4 (14.3%)	5 (12.5%)	9 (13.2%)
Unknown	2	0	2

- In this study, mostly gynecologic cancers, some breast CA, some colon CA
- Pts had received Taxane or Platinum, mostly
- All pts >6 months chemotherapy-free
- Most on adjunct meds (gabapentin, vitamin B or other)

Table 1
Modified total neuropathy score, adapted from Cornblath et al. [21]. (Modified TNS)

	Score				
Parameter	0	1	2	3	4
Sensory symptoms	None	Limited to fingers and toes	Symptoms extend to wrist/ankle	Symptoms extend to knee/elbow	Symptoms extend beyond knee/elbow or are disabling
Motor symptoms	None	Slight difficulty (independent)	Moderate difficulty (independent)	Requires assistance	Paralysis
Pin sensitivity	Normal	Reduced in fingers/toes	Reduced up to wrist/ankle	Reduced up to elbow/knee	Reduced beyond elbow/knee
Vibration sensitivity	Normal	Reduced in fingers/toes	Reduced up to wrist/ankle	Reduced up to elbow/knee	Reduced beyond elbow/knee
Motor/strength	Normal	Mild weakness	Moderate weakness	Severe weakness	Paralysis
Tendon reflexes	Normal	Reduced at ankle	Absent at ankle, normal at knee	Absent at ankle, reduced at knee	All reflexes absent

P.A. Argenta et al. / Gynecologic Oncology 144 (2017) 159–166

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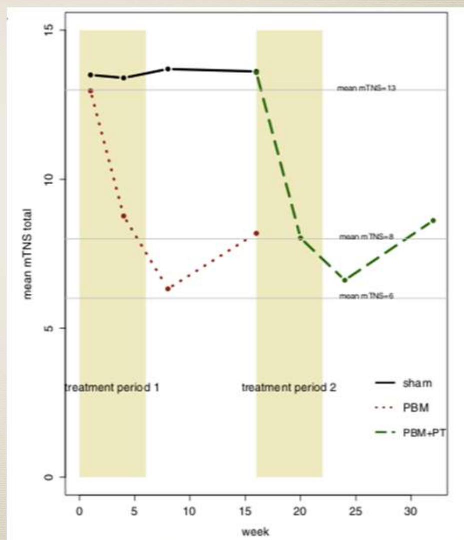
The effect of photobiomodulation on chemotherapy-induced peripheral neuropathy: A randomized, sham-controlled clinical trial

P.A. Argenta et al. / Gynecologic Oncology 144 (2017) 159–166

- **Results**:
  - PBM treatments: 3 per wk for 6 wks was well-tolerated and significantly reduced clinical manifestations of CIPN compared to sham therapy.
  - Addition of PT to PBM did not improve results over PBM alone.



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LLLT/PBM: Clinical Applications

- Minor muscle and joint pain
- Arthritis and muscle spasm
- Joint stiffness
- Promoting relaxation of muscle tissue
- Temporarily increasing local blood circulation
- Chronic and Acute Pain
- Regeneration of Nervous Tissue
- Trigeminal Neuralgia/PHN
- Reduces Inflammation
- Tendinopathies
- Epicondylitis
- Back Pain / Neck Pain
- Sacroiliac joint pains
- Wound Healing
- Bone Healing (Dental)
- Carpal Tunnel Syndrome

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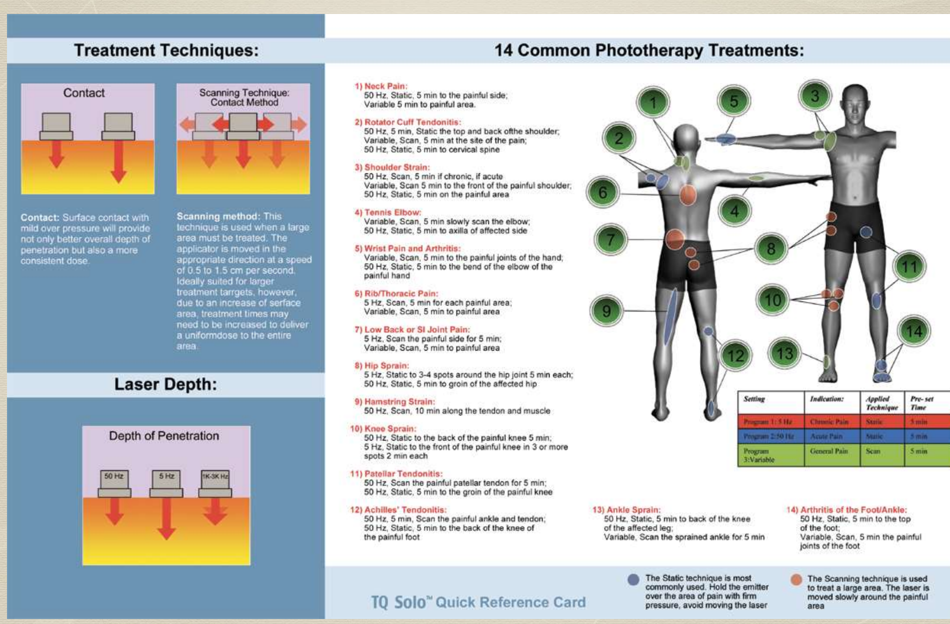
LLLT/PBM: Techniques



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Facial Nerve Injury
12 years post-surgical

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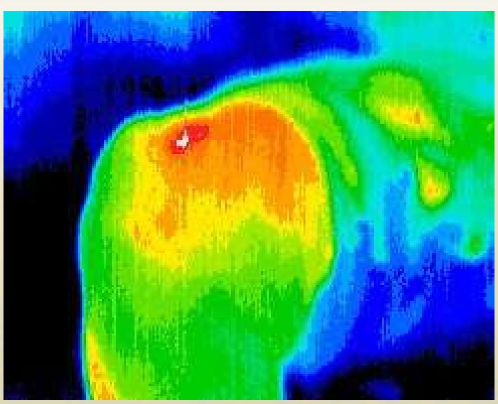
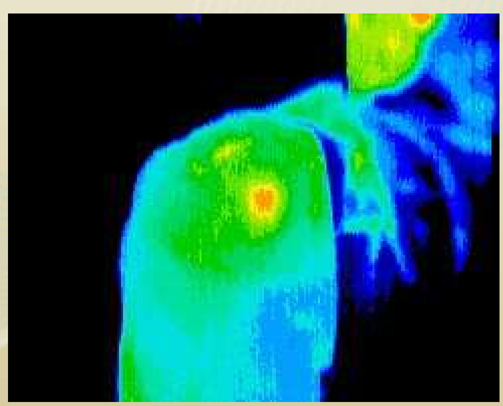
Knee OA: IR Thermogram



Before treatment

After 11 minute treatment



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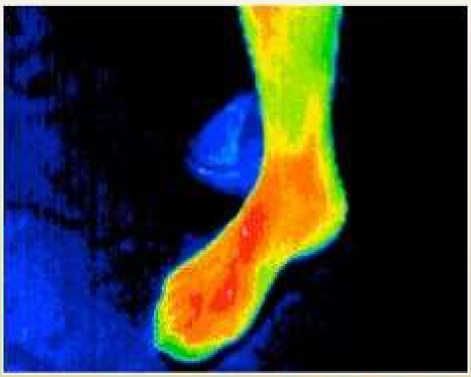
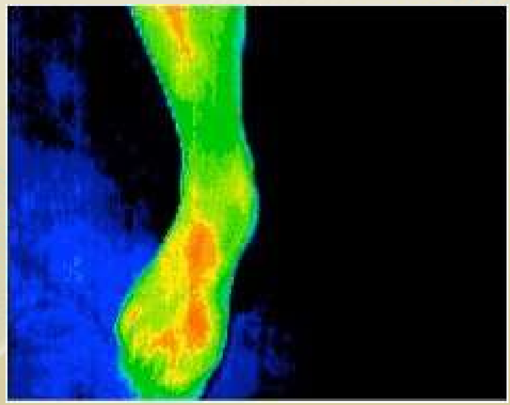
Foot Trauma: IR Thermogram



Before treatment

After 10 minute treatment



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AUTOMOBILE COLLISION
February 24, 2008

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PATIENT ON THE DAY OF THE COLLISION
Hospital Evaluation on 24 February 2008

- Inferior orbit fracture
- Hematoma
- Unable to move left side of face

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AUTOMOBILE COLLISION
Four Days Later

- Patient felt he is getting worse
- Unable to move eyes laterally

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AUTOMOBILE COLLISION
Third Treatment - Able to Smile

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Collision Patient after 5 Laser Treatments in 15 Days

5 Laser Treatments

Dr. Mathesie, DC
Lumix 250

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