


Peter Vitruk, PhD, MInstP, CPhys  
The Physics and Myths of Surgical Lasers

# Laser Surgery: Myths & Physics of Soft Tissue Lasers

( Wavelength, Pulsing, Absorption, Scattering, Coagulation, Ablation )

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PhD, MInstP, CPhys



The Institute of Physics, Member  
American Laser Study Club, Founder, Faculty  
Laser Institute of America (non-conflict) Laser Safety Officer  
LightScapel LLC, Founder

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The opinions expressed in this presentation are those of the speaker .....

The opinions expressed in this course should not be construed as advise to care for specific patients .....

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# What makes a good surgical **laser** ?

## ... **Efficient Cutting** & **Sufficient Hemostasis**

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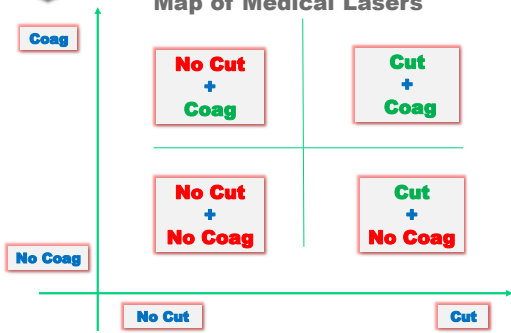
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### Map of Medical Lasers



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## **Laser Frenectomies**

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**Laser Surgery Science:  
Wavelength,  
Absorption & Scattering,  
Pulsing,  
Ablation & Coagulation**

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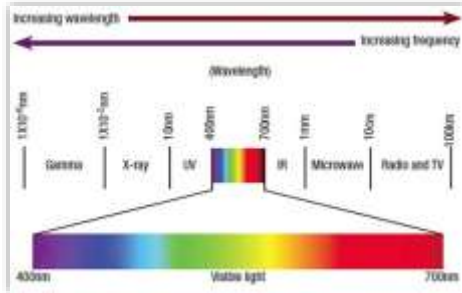
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**What Is Wavelength ?**



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**Practical Soft Tissue ABLATIVE Lasers**

**Does Wavelength MATTER for Cutting ? Coagulation ?**

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**How do Lasers Optically Ablate (incise/excise) Soft Tissue ?**



CO2 laser, muscle tissue incision / chicken leg  
7 Watts, 0.25mm spot size

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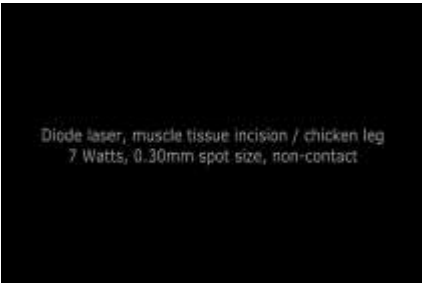
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**How do Lasers Optically Ablate (incise/excise) Soft Tissue ?**



Diode laser, muscle tissue incision / chicken leg  
7 Watts, 0.30mm spot size, non-contact

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**How do Lasers**  
Optically Ablate (incise/excise) Soft Tissue ?

CO<sub>2</sub> Laser @ **10,600 nm**; 7 W CW; 0.25 spot size  
**Does Cut** (ablate/excise/incise)

Diode Laser @ **810 nm**; 7 W CW; 0.3 mm spot size  
**Does Not Cut** (ablate/excise/incise)

**WHY ?**

**WAVELENGTH MATTERS !**

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# MYTHS

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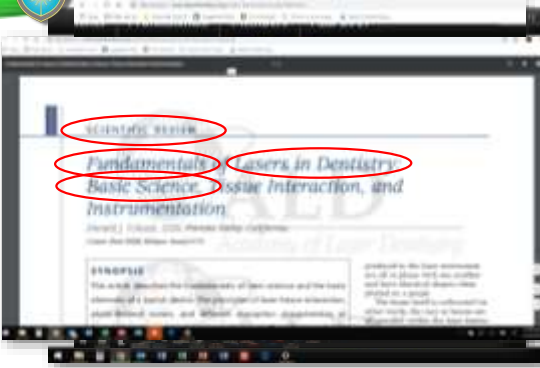
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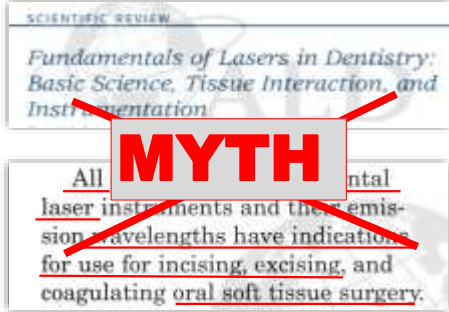
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2008 Journal of Laser Dentistry, Academy of Laser Dentistry



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Laser Surgery "Science" 2008



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Where do we start  
????

Physics !!!

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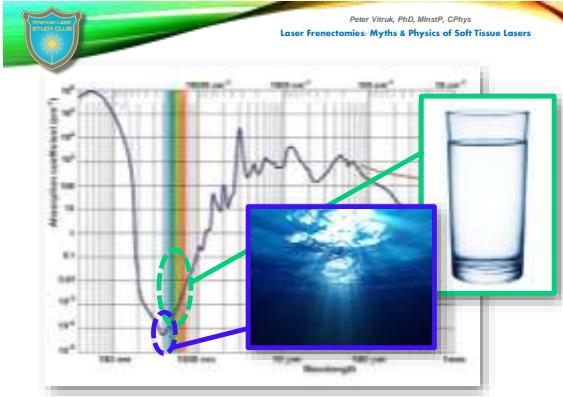
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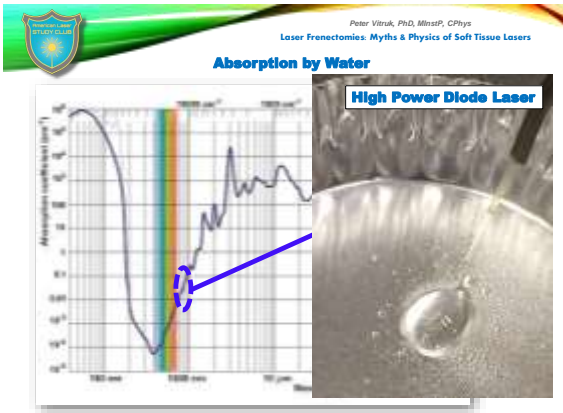
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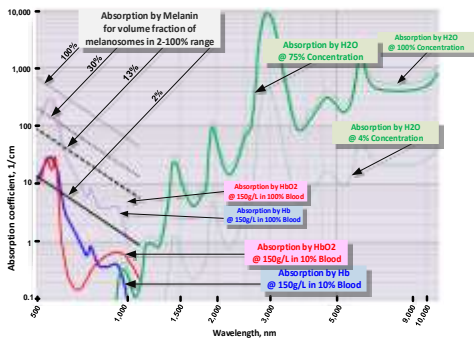
**4 MAIN KNOWN**  
**Soft Tissue Chromophores'**  
**Absorption Coefficient Spectra**

**Water,**  
**Melanin,**  
**Hb,**  
**HbO2**

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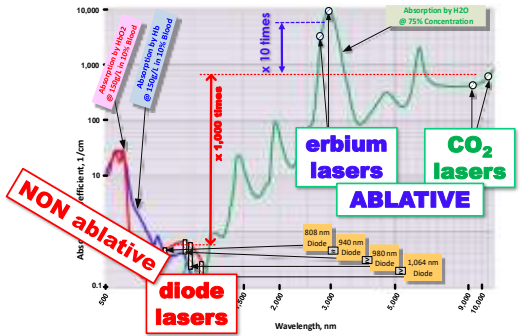
**Absorption Spectra for Main Chromophores**



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**Absorption Spectra for Soft Tissue Main Chromophores**



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Thus, even in an idealised situation, application of high-power laser light (e.g., 20 W) is necessary during several seconds, inducing tissue changes that extend further into the tissue than can be observed by the surgeon. An important complicating factor in the use of this high-power laser light, which penetrates deeply before being absorbed totally, is that it may reach vital structures in the vicinity of the target tissue [21,22]. These vital structures, e.g., large arteries, may preferentially absorb near-infrared laser light because of different optical properties and may be heavily damaged before efficient tissue ablation at the surface is initiated [7].

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# Light Scattering

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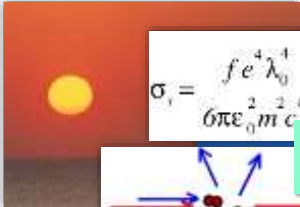
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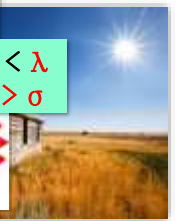


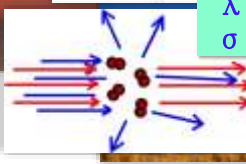
$$\sigma_s = \frac{8}{3} \pi^2 \frac{e^4 \lambda_0^{-4}}{\epsilon_0^2 m^2 c^4} \left( \frac{1}{\lambda} \right)^4$$

**Rayleigh Scattering**

$\lambda < \lambda$

$\sigma > \sigma$





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### Soft Tissue's Light Scattering.

$\lambda < \lambda$   
 $\alpha < \alpha$   
**Light Absorption**

$\lambda < \lambda$   
 $\sigma > \sigma$   
**Light Scattering**

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10,600 nm CW Absorption

400  $\mu$ m glass fiber Tip is In Contact with Porcine Soft Tissue

1 Watt CW 810 nm Diode NIR is Highly Scattered

808-1,064 nm Diodes: Scattering >> Absorption

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## NIR halo ...

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### Laser Ablation (cutting/incising/excising) of Soft Tissue

According to ...  
**Laser Surgery Physics  
Texts ...**

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Library of Congress Cataloging-in-Publication Data  
Endoscopic laser surgery handbook. Scattering-to-Absorption Ratio

2. Lasers whose extinction length is 5 mm or more, and whose **ratio is larger than 10** make good coagulators but poor scalpels. They **cannot** be able to deliver at least 50 W to heat a cubic centimeter or more of soft tissue in a few seconds to 60°C. Such wavelengths are all in the near-infrared (700-1400 nm) region. The Nd:YAG is the best of present lasers for voluminous photopyrolysis in all soft tissues.

**i.e. Near-IR diode wavelengths are Not Good for Ablation (incision/excision)**

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**i.e. Near-IR diode wavelengths are Not Good for Ablation (incision/excision)**

internal reflection lead to a large fluence rate proximal to the tissue surface which can exceed by several times the delivered irradiance.<sup>10,103</sup> It should be noted, however, that using laser wavelengths where optical scattering is comparable to or dominant over tissue absorption is not conducive to precise ablation (see section IV.C).

Figure 5. Ratio of the reduced scattering coefficient to the absorption coefficient of human skin. For wavelengths

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**Thermal Relaxation Time**

**Thermal Diffusivity through the solid medium**  
**Brownian Motion**



**A. Einstein** - Über die von der molekularkinetischen Theorie der Wärme geforderte Bewegung von in ruhenden Flüssigkeiten suspendierten Teilchen", Annalen der Physik, **1905**, vol. 322, Issue 8, pp.549-560

Durch Eliminieren von  $D$  erhalten wir:

**Diffusion (of Heat, or Heat Propagation) Distance is proportional to Root Square of Time**

$$\lambda_e = \sqrt{t} \sqrt{\frac{RT}{N} \frac{1}{3\pi k P}}$$

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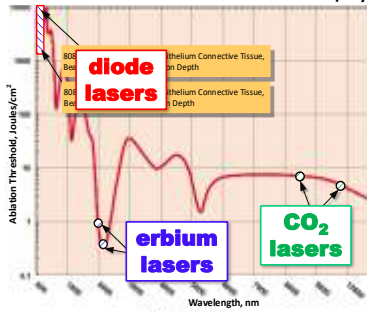
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**ABLATION THRESHOLD FLUENCE, J/cm<sup>2</sup> ?**



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**Coagulation?**

**During Laser Ablation**

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**SUMMARY**

**Near-IR diode wavelengths circa 1,000 nm:**  
 - energy inefficient and spatially inaccurate photo-ablation,  
 - excessive and wide spread thermal damage during coagulation.

**Mid-IR Er laser wavelengths circa 3,000 nm:**  
 - highly efficient and accurate ablation,  
 - radiant coagulation depth smaller than gingival blood vessel diameters,  
 - coagulation depth can be extended by pulse width/rate increase.

**IR CO<sub>2</sub> laser wavelengths circa 10,000 nm:**  
 - highly efficient and accurate ablation,  
 - radiant coagulation depth matches gingival blood vessel diameters,  
 - coagulation depth can be extended by pulse width/rate increase.

**NON ablativ**

**ABLATIVE**  
**Poor Coagulation**

**ABLATIVE**  
**Good Coagulation**

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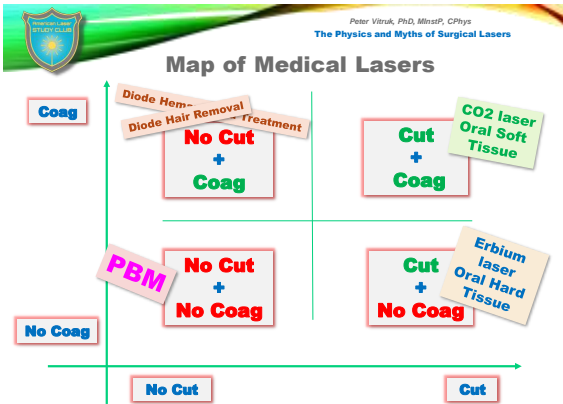
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**VEHICLES – passenger cars**

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**Ablation/Cutting**  
**DEPTH**

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**Ablation/Cutting depth**

- $\delta \propto \text{power}$**
- $\delta \propto \text{spotsize}^{-1}$**
- $\delta \propto \text{handspeed}^{-1}$**

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side cutting  
100% laser  
the miniatur  
first in class

**Zaghi Handpiece**  
for Functional Frenuloplasty  
**Soroush Zaghi, MD**

BREATHE INSTITUTE  
Zaghi Scalpel



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**Post Operative**

***PAIN***

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# Healing

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# THANK YOU !

Peter Vitruk



American Laser Study Club



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