[Training Material]

Picosecond Laser

WONTECH

Ⅰ. Picosecond Laser

01 Picosecond Laser

PICOSECOND

One Trillionth of a second

(0.000000000001 sec)

1000 times shorter than

nanoseconds

10^{-9} → 10^{-12}

PICOSECOND LASER

A laser emission within

picoseconds; 10 times

shorter than Q-switched lasers

5ns (5000ps) → 450ps

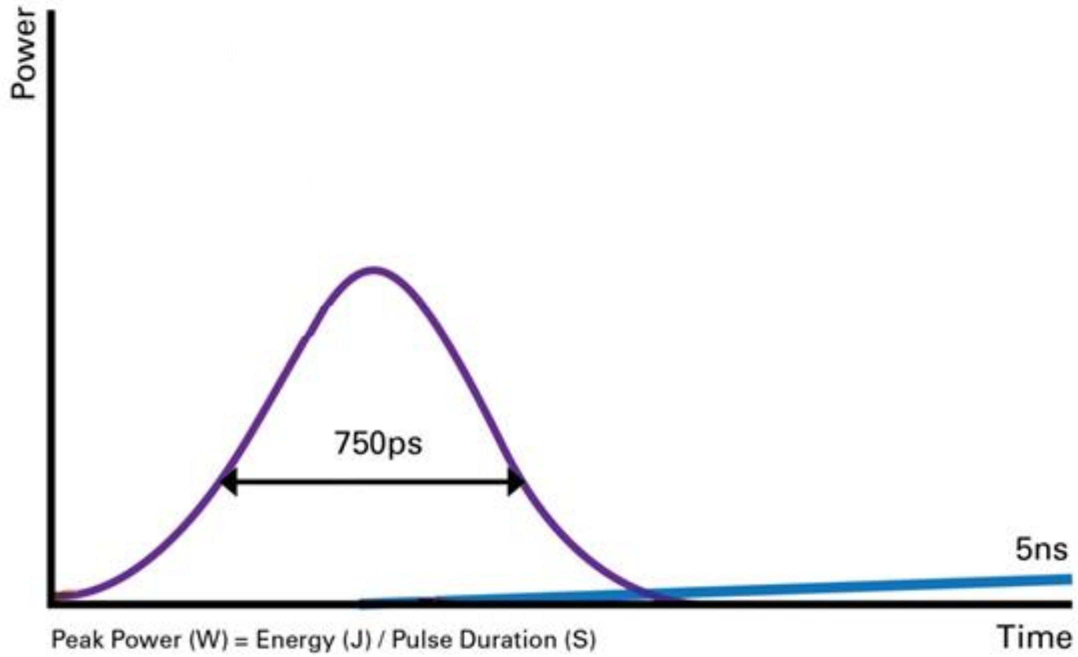
Laser Tissue Interaction

More photoacoustic effects

with Less photothermal effects

TRT → SRT

02 Pulse duration and Peak Power

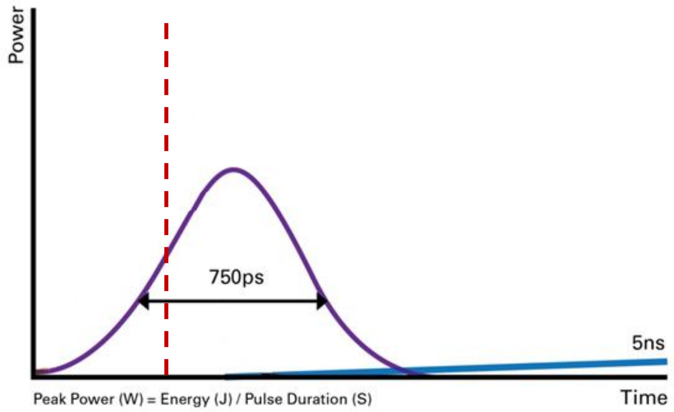


- Under the same energy condition, shorter the pulse duration, higher the peak power.
- Higher the peak power, increase photoacoustic effect.
- Picosecond laser is more excellent for tattoo removal / pigmentation treatment than Nanosecond laser.

03 SRT

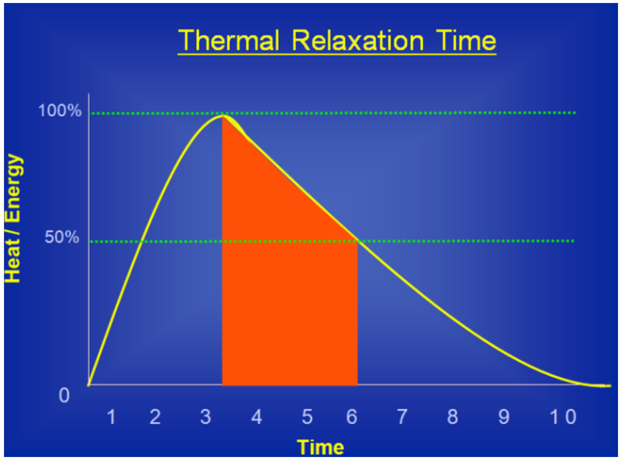
Stress Relaxation Time

- Pre - time that laser energy(shock waves) limited in the target spread to the surrounding tissue.
- Pre-time to photoacoustic effect delivered to the target change into the photothermal effect



Thermal Relaxation Time

- Pre - time that laser energy (photothermal effect) limited in the target spread to the surrounding tissue.
- Time to laser energy is absorbed into the target and temperature of target reduces from top to 1/2



WONTECH

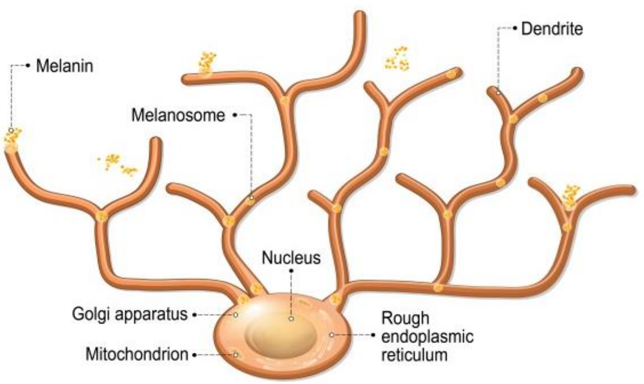
Anderson, R. R & Parrish J. A. (1983). Selective Photothermolysis: Precise Microsurgery by Selective Absorption of Pulsed Radiation. *Science, New Series, 220(4956)*: 524-527.

03 SRT (Cont.)

Pigments

- The Size of Melanin : 15nm
- TRT : 400ps
- SRT : 10ps

- The Size of Melanosome : 0.5um (=500nm)
- TRT : 500ns
- SRT : 300ps



Tattoos

- The Size of Tattoo Particle : 500nm
- TRT : 1000ps
- SRT : 100ps

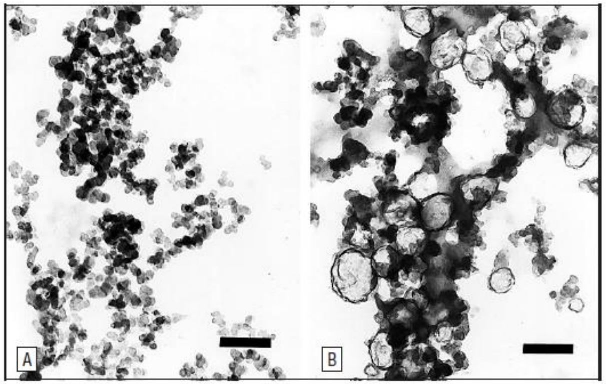
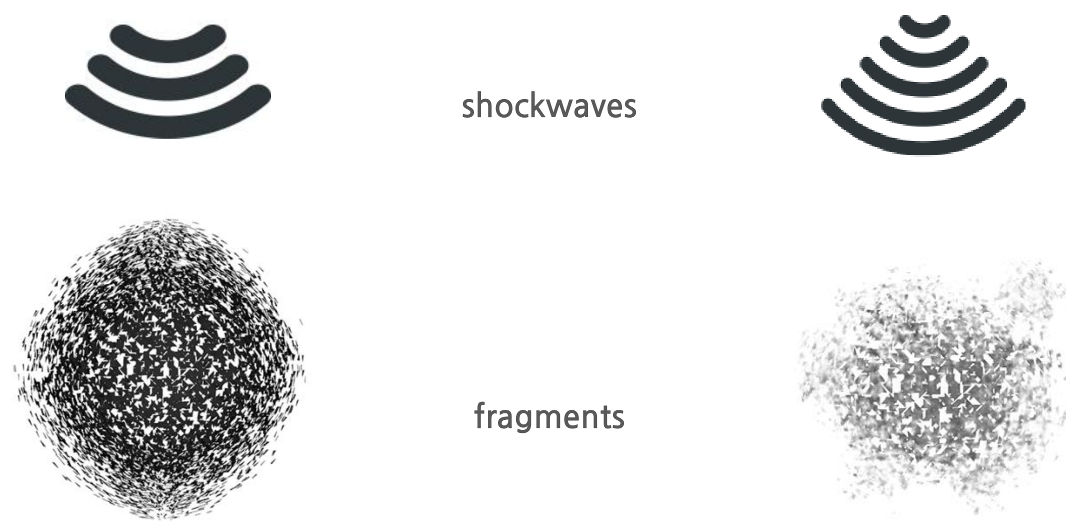


Figure 3. *Electron micrographs showing in vitro suspension. A, Pretreatment particles of relatively uniform shape and size. B, Posttreatment enlarged "bubblelike" particles mixed with apparently unaltered particles (original magnification ×62 400); bars represent 0.2 μm.*

Strauss, M., et al. (1997). Computational modeling of stress transient and bubble evolution in short-pulse laser irradiated melanosome particles. Proc. SPIE 2975, Laser-Tissue Interaction VIII, doi: 10.1117/12.275491; https://doi.org/10.1117/12.275491
Ho, d. D. -M., et al. (2002). Laser-Tattoo Removal-A Study of the Mechanism and the Optimal Treatment Strategy via Computer Simulations. Lasers in Surgery and Medicine, 30:389-397.
Ross, CDR. E., et al. (1998). Comparison of Responses of Tattoos to Picosecond and Nanosecond Q-Switched Neodymium: YAG Lasers. *Archives of Dermatology,* 134, 167-171.

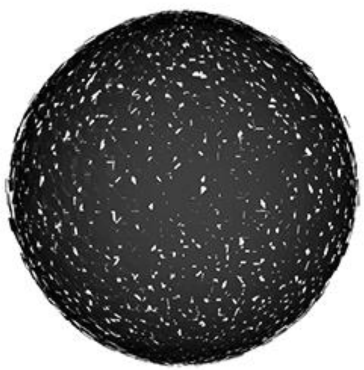
04 Mechanisms

Laser Type	Q/Switched Laser	Picosecond Laser
Consideration	TRT (Thermal Relaxation Time)	SRT (Stress Relaxation Time)
Laser Tissue interactions	Rapid heating -> expanding the particles -> thermal stress -> fracture of particle	Photoacoustic stress -> shock waves -> fracture of particle



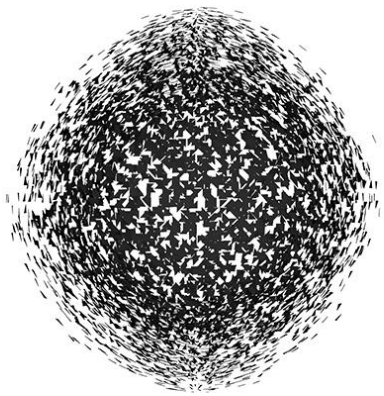
04 Mechanisms (Cont.)

Untreated Pigment / Ink



| Rocks |

Q-Switched Laser



| Pebbles |

Picosecond Laser

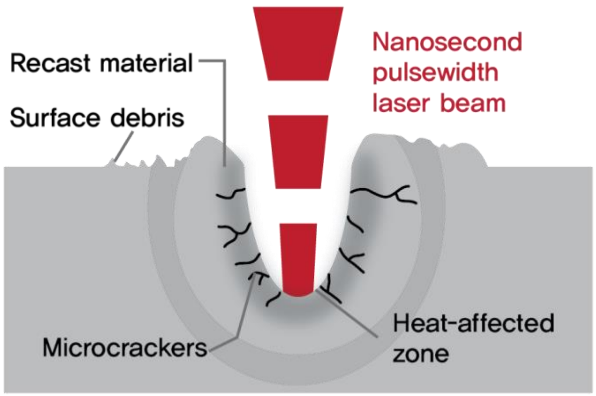
| Sand |

Picosecond lasers deliver more photoacoustic effects to pigment particles,

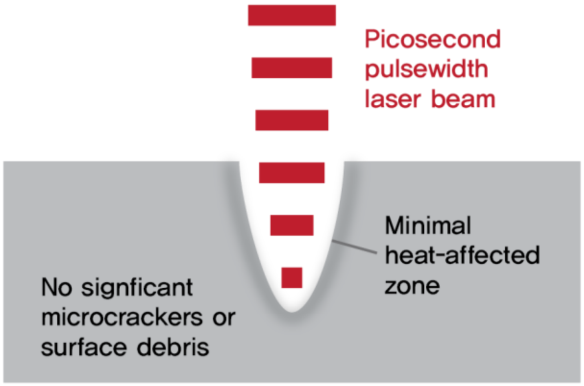
resulting in fast and better results in tattoo removal and pigmentation treatment

by fragmenting pigment particles into smaller sizes that can be more easily removed by lymphatic system.

04 Mechanisms (Cont.)



| Q-Switched Laser |



| Picosecond Laser |

With more photomechanical effects, Better efficacy of treatment

With less photothermal effects, Less collateral damage

05 Comparisons with Nano and Pico

General Differences

Laser Type	Q/Switched Laser	Picosecond Laser
Pulse duration	One Billionth of a second =0.000000001 sec = 10^{-9} sec	One Trillionth of a second = 0.000000000001 sec = 10^{-12} sec
Actual Pulse duration	5-10ns	450-750ps
Peak power	High	Higher
Mechanism	Photoacoustic + photothermal	Photoacoustic
Consideration	TRT (Thermal Relaxation Time)	SRT (Stress Relaxation Time)
Collateral damage	↑	↓
No. of Tx	↑	↓

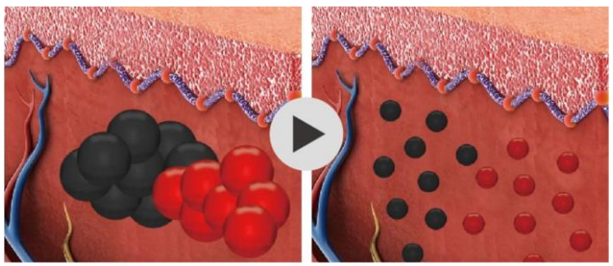
06 Comparisons with Nano and Pico

Clinical Differences

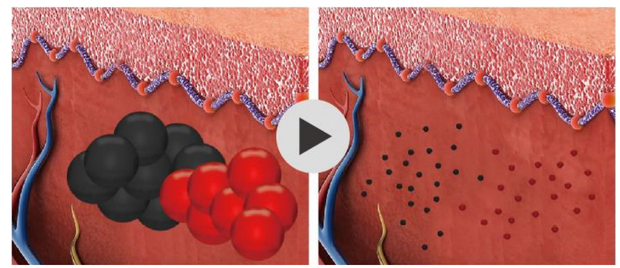
		Q-Switched Lasers	Picosecond Lasers
Pigments Treatment	No. of Tx	5-10 sessions	3-5 sessions
	Efficacy	Good	Better Effective in recalcitrant pigments
	Side effects	Hypopigmentation or Hyperpigmentation	Less
Laser Toning	No. of Tx	5-10 sessions	3-5 sessions
	Efficacy	Good	Better
	Side effects	Hypopigmentation	Less
Tattoo Removal	No. of Tx	5-10 sessions	3-5 sessions
	Efficacy	Good	Better
	Side effects	Scarring, textural change, hypopigmentation, hyperpigmentation	Less

07 Features of Picosecond laser

- Picosecond lasers treat lesions with 1/3 to 1/2 of the energy used in nanosecond lasers.
- Picosecond lasers break down tattoo/pigment particles into smaller sizes that easily remove them through the lymphatic system.



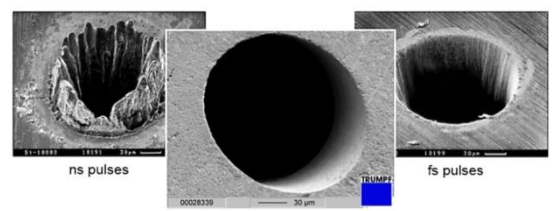
Nanosecond laser



Picosecond laser

- Picosecond lasers can more effectively eliminate difficult colors than nanosecond lasers.

- Picosecond lasers have more photoacoustic effects and less photothermal effects, compared to nano-second lasers. Therefore, the risk of collateral damages to surrounding tissues is less.



C. Momma, B.N. Chichkov, S. Nolte, F. von Alvensleben, A. Tünnermann, H. Welling, B. Wellegehausen, "Short-pulse laser ablation of solid targets", Opt. Commun. 129, 134 (1996)

WONTECH

STUDY

ONLINE FIRST

Treatment of Tattoos With a Picosecond Alexandrite Laser

A Prospective Trial

Scan for Author Audio Interview

Nazanin Saedi, MD; Andrei Metelitsa, MD, FRCPC; Kathleen Petrell, BS; Kenneth A. Arndt, MD; Jeffrey S. Dover, MD, FRCPC

Objective: To study a picosecond 755-nm alexandrite laser for the removal of tattoos to confirm the efficacy of this therapy, focusing on the effect of therapy on the target lesion as well as the surrounding tissues and quantifying the number of necessary treatments.

Design: Fifteen patients with tattoos were enrolled. Treatments were scheduled approximately 6 ± 2 weeks apart. Standard photographs using 2-dimensional imaging were taken at baseline, before each treatment, and 1 month and 3 months after the last treatment.

Setting: Dermatology clinic at SkinCare Physicians in Chestnut Hill, Massachusetts.

Patients: Fifteen patients with darkly pigmented tattoos.

Main Outcome Measures: Treatment efficacy was assessed by the level of tattoo clearance in standard photographs. These photographs were assessed by a blinded physician evaluator and based on a 4-point scale. Efficacy was also assessed based on physician and patient satisfaction measured on a 4-point scale.

Results: Twelve of 15 patients with tattoos (80%) completed the study. All 12 patients obtained greater than 75% clearance. Nine patients (75%) obtained greater than 75% clearance after having 2 to 4 treatments. The average number of treatment sessions needed to obtain this level of clearance was 4.25. All 12 patients (100%) were satisfied or extremely satisfied with the treatment. Adverse effects included pain, swelling, and blistering. Pain resolved immediately after therapy, while the swelling and blistering resolved within 1 week. Hypopigmentation and hyperpigmentation were reported at the 3-month follow-up.

Conclusion: The picosecond 755-nm alexandrite laser is a safe and very effective procedure for removing tattoo pigment.

Arch Dermatol. 2012;148(12):1360-
Published online September 17, 2012
doi:10.1001/archdermatol.2012.289

4.25 tx

OBSERVATION

ONLINE FIRST

Successful and Rapid Treatment of Blue and Green Tattoo Pigment With a Novel Picosecond Laser

Jeremy A. Brauer, MD; Kavitha K. Reddy, MD; Robert Anolik, MD; Elliot T. Weiss, MD; Julie K. Karen, MD; Elizabeth K. Hale, MD; Lori A. Brightman, MD; Leonard Bernstein, MD; Roy G. Geronemus, MD

Background: While the understanding and technology of laser tattoo removal has advanced much over the last 5 decades, treatments and results remain far from perfect. With currently available devices, treatment courses are often painful and prolonged with mixed results. We describe the successful and rapid treatment of 12 tattoos containing blue and/or green pigment with a novel, picosecond, 755-nm alexandrite laser.

Observations: All previously untreated multicolo[…] tattoos as well as tattoos recalcitrant to treatment de[…]onstrated at least 75% clearance of blue and green p[…]ment after 1 or 2 treatments with a novel, picosecond, 755-nm alexandrite laser. More than two-thirds of these tattoos approached closer to 100% clearance.

Conclusions: While additional future studies are needed, we believe that this new technology is more effective in targeting blue and green pigment, resulting in expedited clearance with less collateral injury to surrounding tissue.

75% clearance by 1-2 tx

A Novel Dual-Wavelength, Nd:YAG, Picosecond-Domain Laser Safely and Effectively Removes Multicolor Tattoos

Eric F. Bernstein, MD, MSc (Eng),[1]* Kevin T. Schomacker, PhD,[2] Lisa D. Basilavecchio, RN,[1] Jessica M. Plugis,[1] and Jayant D. Bhawalkar, PhD[2]
[1]*Main Line Center for Laser Surgery, Ardmore, Pennsylvania 19003*
[2]*Syneron-Candela Corporation, 530 Boston Post Road, Wayland, Massachusetts 01778*

Background and Objectives: Although nanosecond-domain lasers have been the mainstay of laser tattoo removal for decades, recent disruptive innovations in laser design have introduced a new class of commercial Q-switched lasers that generate picosecond-domain pulses.
Study: A picosecond-domain, Nd:YAG laser with a KTP frequency-doubling crystal was used to treat 31 decorative tattoos in 21 subjects. Safety and effectiveness were determined by blinded evaluation of digital images in this prospective clinical study.
Results: The average clearance overall as evaluated by blinded observers evaluating randomized digital photographs was 79 ± 0.9% (mean ± sem) after an average of 6.5 treatments. Of the 31 tattoos completing treatment, 6 had evidence of mild hyper- or hypo-pigmentation by evaluation of photographs.
Conclusion: The 350 picosecond, 532 nm, and 450 picosecond 1,064 nm Nd:YAG laser is safe and effective for removing decorative tattoos. Lasers Surg. M[…] 47:542–548, 2015. © 2015 The Authors. *Lasers in Su[…] and Medicine* Published by Wiley Periodicals, Inc.

Key words: tattoo; picosecond; pulse-duration; […]ment; laser

available with pulse-durations from approximately 50–100 ns as is typical of Q-switched alexandrite lasers, to about 20–50 ns pulse-durations of ruby lasers, down to approximately 5–10 ns pulse-durations available with Q-switched Nd:YAG lasers [2]. Nanosecond-domain Q-switched lasers have been the gold-standard for tattoo removal for decades, with gradual improvements in laser design enabling higher fluences with large beam-diameters being introduced over many years [12].

Recent disruptive innovations in laser design have introduced a new class of commercial Q-switched lasers that generate picosecond-domain pulses [13,14]. Prototype, research lasers in the picosecond-domain were available 20 years ago and demonstrated effectiveness at removing tattoos [15]. Tattoos are created by injecting pigments intra-dermally after which the ink particles are aggregated in resident dermal cells such as perivascular fibroblasts, mast cells and macrophages, where pigment is mostly […] been treated by a Q-switched lasers measuring 0.2–1.0 µm,

80% clearance by 6.5 tx

Clearance of Yellow Tattoo Ink With a Novel 532-nm Picosecond Laser

Hamad Alabdulrazzaq, MBChB,[1]* Jeremy A. Brauer, MD,[1,2] Yoon-Soo Bae, MD,[1] and Roy G. Geronemus, MD,[1,2]
[1]*Laser & Skin Surgery Center of New York, New York, New York 10016*
[2]*Ronald O. Perelman Department of Dermatology, NYU Langone Medical Center, New York, New York 10016*

Background and Objectives: Although technology and tattoo removal methods continue to evolve, yellow pigment clearance continues to be challenging and usually unsuccessful. We describe a case series of six tattoos containing yellow ink, successfully treated with a frequency-doubled Nd:YAG 532-nm picosecond laser.
Study Design/Materials and Methods: Case series with six subjects participating for the treatment of multicolored tattoos that contain yellow pigment. Treatments performed with a frequency-doubled Nd:YAG 532-nm picosecond laser at 6–8 week intervals.
Results: One subject achieved complete clearance of the treated site after one session, and five subjects required 2–4 treatments to achieve over 75% clearance. Minimal downtime was experienced, and no scarring or textural skin changes were observed in any of the treated sites.
Conclusions: This is the first case series that demonstrates effective and consistent reduction of yellow tattoo ink using a frequency doubled Nd:YAG 532-nm laser with a picosecond pulse duration. Treatments were well tolerated and subjects had positive outcomes. This is a small observational case series from an ongoing clinical trial, and studies with a larger sample size and con[…]tive group are needed in the future. Lasers Surg. […] 47:285–288, 2015. © 2015 Wiley Periodicals, Inc.

Key words: frequency doubled; Nd:YAG; pigment; […]

any given tattoo [6]. However, complete removal can never be guaranteed and residual pigment often remains after multiple sessions.

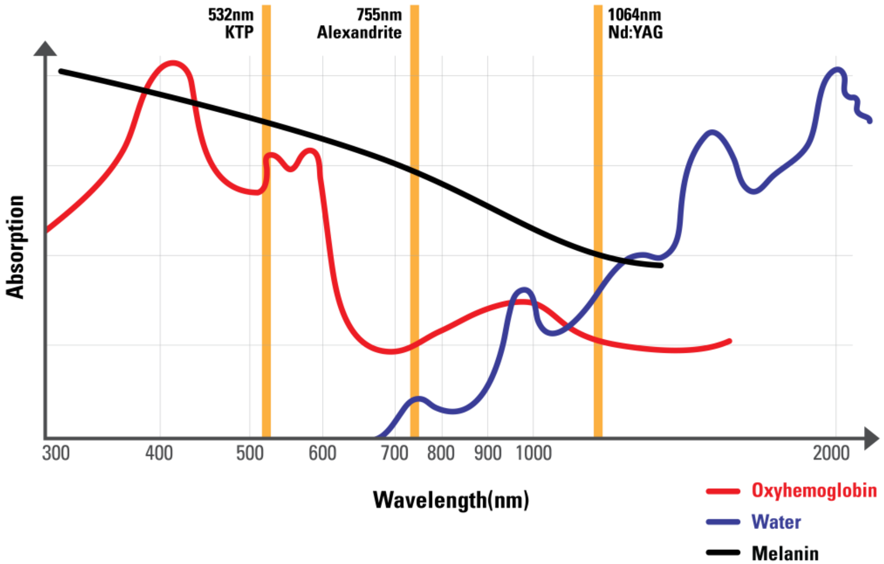
Tattoo color is one of the main predictors of clearance, and with the introduction of the alexandrite picosecond laser [1,2], blue and green pigments can now be effectively cleared with few treatments. On the other hand, there is no established and definitive treatment for yellow pigments, as the dye is not well absorbed by the current available wavelengths. Yellow dyes are typically made of cadmium sulfide, ochre, Pigment Yellow 74, chrome yellow, or curcuma yellow, and are currently treated with the Q-switched frequency doubled Nd:YAG laser with a nanosecond pulse duration, but clearance remains difficult and inconsistent. A study by Ferguson on treating multicolored tattoos with an Nd:YAG Q-switched device with a nanosecond pulse width, demonstrated an improvement of 2 out 8 tattoos that contained yellow pigment, emphasizing the difficulty in clearing yellow ink. Respectively, 6 and 9 treatments were required to obtain pigment reduction, though no clearance percentages were documented [7].

We present a small case series with a unique finding […]

75% clearance by 2-4 tx

Ⅱ. Applications of Picosecond Lasers

01 Wavelengths



	532nm	1064nm	755nm
Melanin	650	65	200
Hemoglobin	260	4	4
gap	2.5X	16X	50X

532nm

- Melanin absorbance+++
- Absorbance gap between Melanin and HbO2 --
- Penetrate to the epidermal layer
- 1064nm
- Melanin absorbance +++
- Absorbance gap between Melanin and HbO2 --
- Penetrate to the epidermal layer.

- 755nm
- Melanin absorbance ++
- Absorbance gap between Melanin and HbO2 ++
- Penetrate to the upper part of epidermal layer

WONTECH

02 532nm vs 755nm vs 1064nm

Pigmentation Treatment

Pico 532nm	Pico 1064nm	Pico 755nm
• Fitzpatrick Skin types Ⅰ-Ⅲ • Epidermal pigmentation (Seb.K, lentigo, freckle) • Recalcitrant pigmentation (Café-Au-Lait, Becker's Nevus)	• Fitzpatrick Skin types Ⅳ-Ⅵ • Epidermal and Dermal Pigmentation (Ota Nevus) • Recalcitrant pigmentation (Becker's Nevus) • Brightening (toning)	• Fitzpatrick Skin types Ⅲ-Ⅳ • Epidermal and dermal pigmentation • Recalcitrant pigmentation (Café-Au-Lait, Becker's Nevus) • Brightening (toning)

WONTECH

03 532nm vs 755nm vs 1064nm

Tattoo Removal

	Dark Brown	Light Brown	Red	Orange	Yellow	Green	Blue	Purple	Black
532nm		O	O	O	O				
595nm							O		
660nm						O	O	O	
755nm	O					O	O	O	O
1064nm	O					O	O	O	O

Choudhary, S., et al. (2010). Lasers for tattoo removal: a review. *Lasers in Medical Science*, 25:619-627.
Kirby, W., et al. (2013). Causes and Recommendations for Unanticipated Ink Retention Following Tattoo Removal Treatment. *Clinical Aesthetic Dermatology*, 6(7), 27-31.

Ⅲ. LIOB
(Laser Induced Optical Breakdown)

01 Laser Induced Optical Breakdown

Ultra-Short Pulse + Higher Energy Intensity = Laser Induced Optical Breakdown

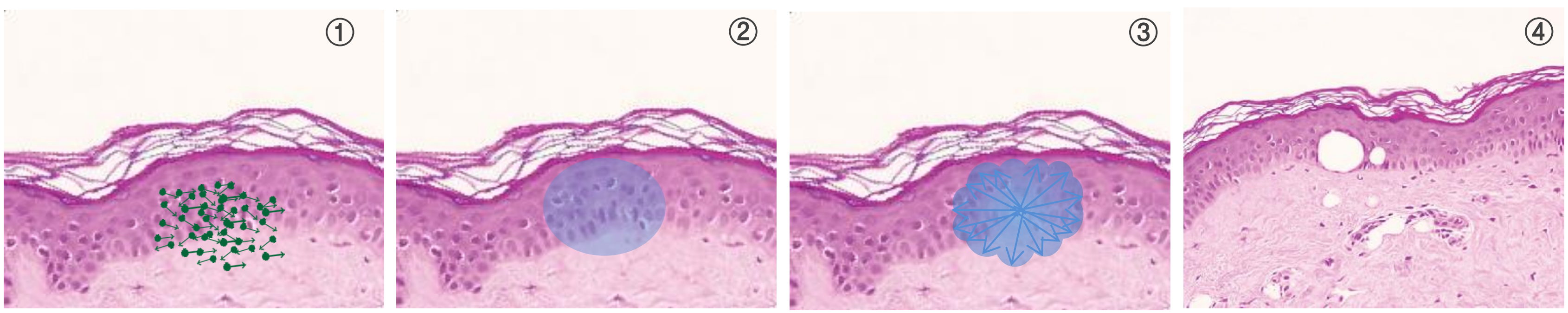
Plasma Induced Ablation

"Non-Linear Absorption"

WONTECH

Oraevsky, A. A., et al. (1996). Plasma mediated ablation of biological tissues with nanosecond-to-Femtosecond Laser Pulses: Relative Role of Linear and Nonlinear Absroption. *IEEE JOURNAL OF SELECTED TOPICS IN QUANTUM ELECTRONICS*, 2(4), 801-809.

02 LIOB process



- Higher Power Density →
- Multiphoton ionization →
- ① Cascade Avalanche →
- ② Plasma formation →
- Plasma expansion →
- ③ Shock waves formation →
- ④ Cavitation bubbles formation →
- Cavitation bubbles collapse →
- Tissue damaged →
- Inflammatory process initiated

WONTECH

03 Plasma

"The fourth state of matter plasma"

At the high temperature, material turns to solid -> liquid ->gas, in this state, when the high energy is given cations and electrons change into plasma.

Conditions

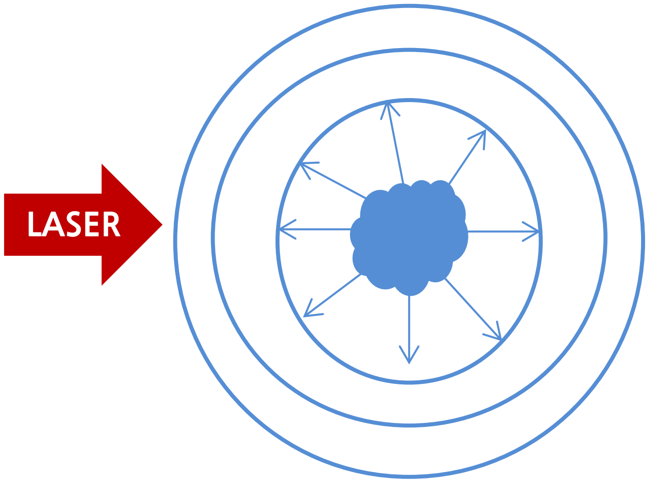
- Energy density $10^{10\sim11}$ W/cm^2
- Free electron density : $10^{19\sim21}$ cm^{-3}

Consequence

- Multiphoton ionization
- Cascade avalanche

Oraevsky, A. A., et al. (1996). Plasma mediated ablation of biological tissues with nanosecond-to-Femtosecond Laser Pulses: Relative Role of Linear and Nonlinear Absroption. *IEEE JOURNAL OF SELECTED TOPICS IN QUANTUM ELECTRONICS,* 2(4), 801-809.

04 Shock waves



Shock waves
= Stress waves
= Stress pressures

"Laser-induced stress waves can be generated by one of the following mechanisms : optical breakdown, ablation, or rapid heating of an absorbing medium"

Doukas, A. G. & Flotte, T. J. (1996). Physical characteristics and biological effects of laser-induced stress waves. The World Federation for *Ultrasound in Medicine and Biology,* 22(2), 151-164.

"High power pulsed laser (above 1GW/cm^2) interacts with matter to produce very high amplitude pressures."

Boustie, M., et al. (2008). Laser Shock Waves: Fundamentals and Applications. *Laser Ultrasonics,* doi: https://www.ndt.net/article/laser-ut2008/papers/Boustie%20LU2008.pdf.

"Molecular reorientation and vibrational motion in the liquid"

Nesterova, E. V & Alekasandrov, I. V. (1985). Envelope shock waves on picosecond light pulses in isotropic liquid. *Sov. Phys, JETP,* 61(1), 55-61.

WONTECH

05 LIOB with Current Picosecond Lasers

Lasers in Surgery and Medicine 50:37–44 (2018)

A Comparative Study With a 755 nm Picosecond Alexandrite Laser With a Diffractive Lens Array and a 532 nm/1,064 nm Nd:YAG With a Holographic Optic

Emil Tanghetti, MD[1] and John Jennings, MD[2]
[1]*Center for Dermatology and Laser Surgery, Sacramento, California*
[2]*Goldsboro Skin Center, Goldsboro, North Carolina*

DISCUSSION

The advent of high energy picosecond lasers with fractional methods of delivery has provided an opportunity to explore a new way to wound the skin creating very localized areas of injury with very little adjacent tissue damage. This process appears to be initiated in the skin by the absorption of the light by melanin in the epidermis, which results in the production of a seed electron. As the energy is delivered during the laser pulse this process continues with the creation of a very localized area of heating by the creation of a small steam bubble. This results in small 40–60 micron vacuoles in the epidermis with very little adjacent tissue damage.

Lasers in Surgery and Medicine 49:555–562 (2017)

In Vivo Multiphoton-Microscopy of Picosecond-Laser-Induced Optical Breakdown in Human Skin

Mihaela Balu,[1*] Griffin Lentsch,[1] Dorota Z. Korta,[2] Karsten König,[3,4] Kristen M. Kelly,[2] Bruce J. Tromberg,[1] and Christopher B. Zachary[2]
[1]*Beckman Laser Institute, Laser Microbeam and Medical Program, University of California Irvine, Irvine, California 92612*
[2]*Department of Dermatology, University of California, Irvine, California 92697*
[3]*JenLab GmbH, Schillerstrasse 1, Jena, Germany*
[4]*Department of Biophotonics and Laser Technology, Saarland University, Saarbrücken, Germany*

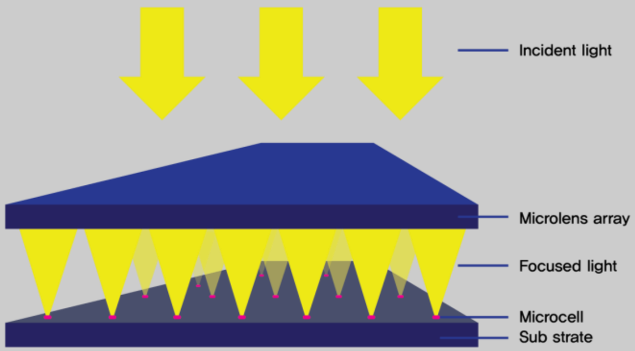
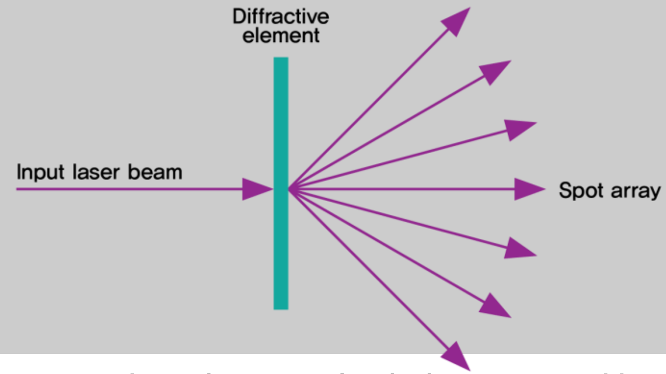
Habbema et al. [2], a diffractive microlens array and a holographic beam-splitter were used for the lasers in the study by Tanghetti [1], and in this work, respectively. Yet, it is noteworthy that both 532 and 1064 nm PicoWay wavelengths generated micro-injuries in the epidermis only, with the LIOB mechanism being triggered by the laser light absorption of melanin. The damage of individual pigmented cells was clearly visualized by MPM, 3 hours post-treatment for 532 nm and 24 hours post-treatment for both 532 and 1064 nm wavelengths. They had the appearance of ruptured cells presenting with enlarged and irregularly shaped nuclei when compared to normal cells in their vicinity. The

- Current Picosecond Laser : Subnanoseconds
- Mechanism = Absorption + Ionization

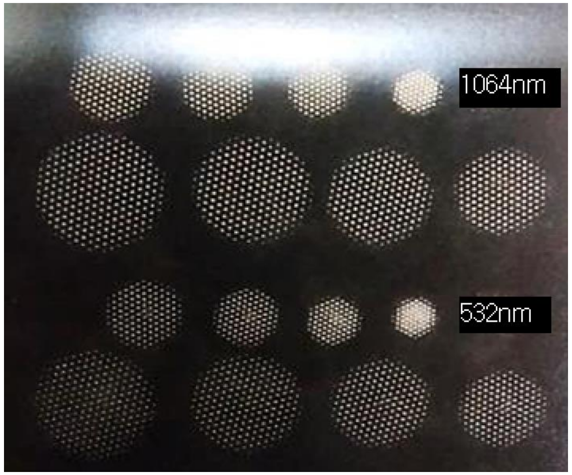
WONTECH

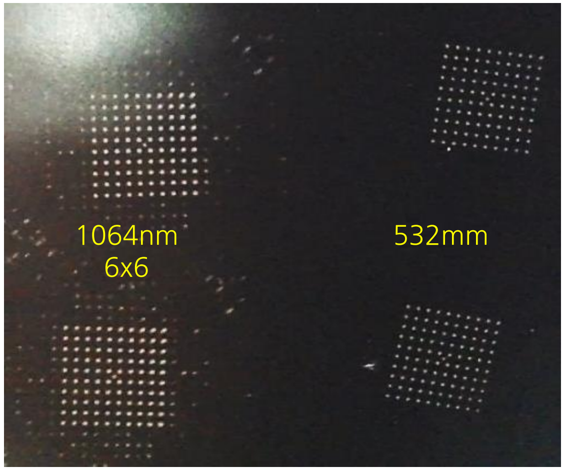
Ⅳ. Fractional Handpiece

01 Types of Fractional Handpieces

Types	MLA MicroLens Array	HOE Holographic Optical Elements
Mechanisms		
Explanation	A structure in which several dependent micro lens converge energy in lens. Energy density increase because energy is concentrated on each microlens	One laser beam is divided into several laser beam and increase the energy intensity by adding the lens that converges the light to reinforce the weakened output.
Energy Intensity	Equal intensity in every fractionated beam sufficient for creating LIOB	Center; higher intensity Peripheral; lower intensity Difficult for creating LIOB
Practical aspect considering beam quality	When treating large area, overlap of spots induce natural pattern	Overlap of spot induce over-treated zone
Products	PICOCARE's HEXA MLA, Enlighten's NIFLS, Picosure' FOCUS lens array, Lutronic's Focused dots	Picoway's Resolve

02 HEXA MLA vs Resolve



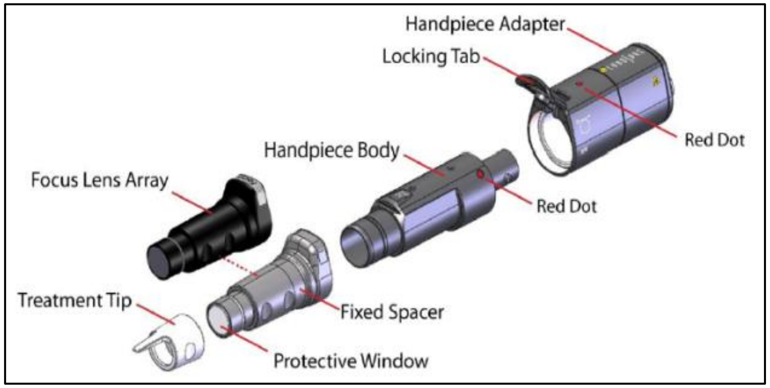


	PICOCARE _ HEXA MLA	S Company's HOE
Spot Size	3-5, 6-10mm	6x6 mm fixed
Shape of the beam	Round shape Useful in acne scar treatment	Square shape
Energy Intensity	Higher energy intensity Effective in both scar treatment and skin rejuvenation	Limited energy intensity Effective in both scar treatment and skin rejuvenation
Shape of the beam	Gaussian mode	Flat-top mode Thermal damage if overlapping

03 HEXA MLA vs Focus

PICOWON _ MLA

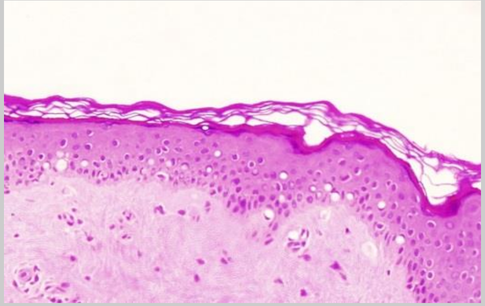
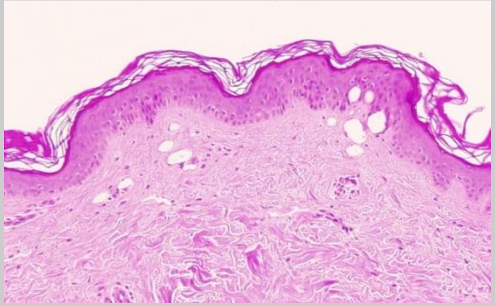
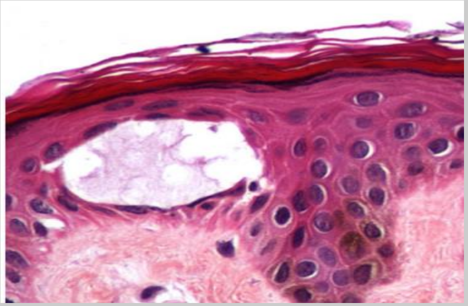
C company's MLA



	PICOCARE _ HEXA MLA	C Company's MLA
Spot Size	3-5, 6-10mm	6, 8, 10mm
Fluence	Adjustable Customizing treatments	Fixed
Replacement	Auto-spot size system	Replace parts to use different spot sizes

Ⅴ. Applications of LIOB

01 Histology of 532nm, 1064nm, 755nm

	532nm	1064nm	755nm
Cavitation bubbles	Epidermis Many small bubbles	Epidermis or Dermis	Epidermis (mostly) or Dermis
Change	Small bubbles in papillary dermis in high fluence	Large bubbles in epidermis in high fluence	Not known
Histology	 PICOCARE _ HEXA MLA by Kangbuk Samsung Hospital	 PICOCARE _ HEXA MLA by Kangbuk Samsung Hospital	 PICOSURE _ FOCUS lens
Application	Fitzpatrick Skin types Ⅰ-Ⅲ Epidermal pigmentation Recalcitrant pigmentation (Café-Au-Lait, Becker's Nevus)	Fitzpatrick Skin types Ⅳ-Ⅵ Epidermal and Dermal Pigmentation Recalcitrant pigmentation (Becker's Nevus, CMN) Scars Skin rejuvenation	Fitzpatrick Skin types Ⅲ-Ⅵ Epidermal pigmentation Skin rejuvenation

02 Clinical Study of 532nm, 1064nm, 755nm

Lasers in Surgery and Medicine 50:37–44 (2018)

A Comparative Study With a 755 nm Picosecond Alexandrite Laser With a Diffractive Lens Array and a 532 nm/1,064 nm Nd:YAG With a Holographic Optic

Emil Tanghetti, MD[1] and John Jennings, MD[2]
[1]*Center for Dermatology and Laser Surgery, Sacramento, California*
[2]*Goldsboro Skin Center, Goldsboro, North Carolina*

Background and Objectives: This study was performed to better understand the cutaneous effects of using a fractional picosecond laser at 755 nm with a diffractive lens array and a picosecond Nd:YAG laser at 532 mn and 1,064 nm with a holographic optic. We characterized the injuries created by these devices on skin clinically and histologically over 24 hours. With this information we modeled the effects of these devices on a cutaneous target.
Methods: Eight patients, representing Fitzpatrick skin types I–VI, were treated on their backs with a picosecond Alexandrite laser with a diffractive lens array, as well as a picosecond Nd:YAG laser at 532 nm and 1,064 nm with a holographic optic. Photographs were taken 15 minutes and 24 hours after treatments. Punch biopsies were obtained at 24 hours and examined histologically.
Results: Treatment with the picosecond Nd:YAG laser at both 532 nm and 1,064 nm with the holographic optic revealed erythema and small scatted areas of petechial hemorrhage areas immediately and in many cases at 24 hours after treatment. The 755 nm picosecond Alexandrite laser with diffractive lens array produced erythema immediately after treatment, which largely dissipated 24 hours later. Histologies revealed intra-epidermal vacuoles with all three wavelengths. Fractional picosecond Nd:YAG laser at 532 nm and 1064 nm with the holographic optic showed focal areas of dermal and intra-epidermal hemorrhage with areas of vascular damage in some patients.
Conclusions: This study demonstrates that both fractional picosecond devices produce vacuoles in the skin, which are most likely due to areas of laser induced optical breakdown (LIOB). In the patients (skin type II–IV) we observed scatter areas of hemorrhage in the skin, due to vascular damage with the 532 nm and 1,064 nm, but not with 755 nm wavelengths. Lasers Surg. Med. 50:37–44, 2018. © 2017 Wiley Periodicals, Inc.

Key words: laser induced optical breakdown (LIOB); superficial hemorrhage; fractional picosecond laser; holographic optic; diffractive lens array

INTRODUCTION

The use of picosecond lasers with fractional optics have provided an opportunity to deliver high energy short pulses of light to the skin. The picosecond Alexandrite 755 nm laser with a diffractive lens array has been used successfully to treat acne scars [1], photo-damaged skin [2], and melasma [3]. We have described the creation of intra-epidermal vacuoles, which appear to be the result of areas of LIOBs from the absorption of high energy 755 nm laser light by melanin in the granular layer of the epidermis [4]. This localized damage has been associated with the production of new collagen and elastic tissue. It is possible that the production of epidermally generated growth factors, cytokines, and chemokines could be responsible for these changes [1,5]. The immediate clinical effects of transient erythema, heat, and swelling with this device lasting less than 24 hours has been well characterized [5]. In individuals with skin types I and II with melanin index (MI) of 12 or less we have described small transient areas of hemorrhage which suggests that hemoglobin in superficial dermal vessels can be a target for this laser in the absence of a sufficient amount of melanin in the epidermis. In individuals with a modest amount of melanin (MI greater than 12) and especially in darker skin types, only short lived erythema and slight swelling is observed.

We have also studied picosecond 532 nm, 1,064 nm, and 755 nm light with a diffractive lens array in order to better understand the comparative effects of these wavelengths on the skin [6]. Clinically, we observed more erythema and areas of hemorrhage across all skin types with the 532 nm and 1,064 nm wavelengths immediately after treatment and at 24 hours on trunk skin. In contrast, treatment with 755 nm with the diffractive lens array showed short lived erythema and mild induration lasting only a few hours. Skin biopsies done 24 hours after treatments with the 532 nm and 1,064 nm wavelengths with the diffractive

Conflict of Interest Disclosures: All authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest and have disclosed the following: Dr. Tanghetti is a consultant for Cynosure, Inc. and has received discounts on equipment purchases and service. Dr. Jennings received financial support from Cynosure, Inc.
*Correspondence to: Dr. Emil Tanghetti, MD, 5601 J Street, Sacramento, CA 95819. E-mail: et@dermatologyandlasersurgery.com
Accepted 5 October 2017
Published online 7 November 2017 in Wiley Online Library (wileyonlinelibrary.com).
DOI 10.1002/lsm.22752

TABLE 1. Listed are the Energies Used Which Each of the Three Wavelengths. Three Passes Were Performed with Each Setting

	532 nm	1,064 nm	755 nm
A	0.2 mJ/dot	1.3 mJ/dot	0.25 J/cm^2
B	0.24 mJ/dot	1.7 mJ/dot	0.4 J/cm^2
C	0.28 mJ/dot	2.1 mJ/dot	0.71 J/cm^2

TABLE 2. Absorption Coefficients for Melanin and Blood for the Three Laser Wavelengths Used for Calculation of the LIOB Threshold Fluence and the Corresponding Temperature Rise in Blood Filled Capillaries at the Dermal/Epidermal Junction

Wavelength, nm		532			1,064			755	
Melanin abs, cm^{-1}		555			50			163	
Blood abs, cm^{-1}		235			3.2			3.0	
Absorption ratio		2.4:1			16:1			54:1	
Epid. Melanin %	2%	15%	43%	2%	15%	43%	2%	15%	43%
LIOB Thresh, J/cm^2	2.8	2.7	2.6	31	30	29	9.5	9.1	8.8
Blood Temp rise, °C	172	105	40	28	25	22	7.8	6.5	4.8

Values colored green are the most advantageous for avoidance of side effects in a clinical treatment, values colored red are the least advantageous and yellow is in intermediate.

02 Clinical Study of 532nm, 1064nm, 755nm

	532nm	1064nm	755nm
Product	450ps, HOE	450ps, HOE	700ps, MLA
Tissue damage	Epidermal vacuoles The more Energy, melanin increase, the more the number and the size of vacuoles increase.	Dermal vacuoules The more Melanin increase, the more the number and the size of vacoules increase.	Epidermal vacuoules with higher fluence
Vascular damage	Superficial dermal hemorrhage The more melanin decreases, the more severe.	Dermal hemorrhage The more melanin decreases, the more severe.	Rare hemorrhage The more Melanin decreases , the more less.
Erythema after lasing	++	+++	+

Histology: 755nm

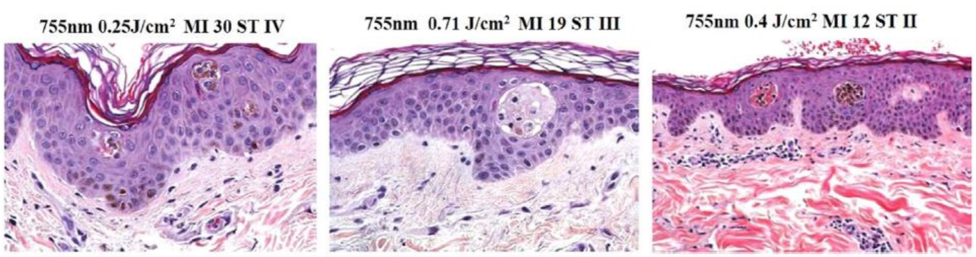


Fig. 4. Seven hundred and fifty-five nanometer- in patients with MI 11–15 intra-epidermal vacuoles were generally observed with the higher fluences. Rare areas of hemorrhage only wit h the patient with an MI of 11. Intra- epidermal vacuoles were routinely observed in with the higher energies with in patients with MI18–24 in. In darker skin types MI 30 and above these vacuoles were seen with all t he energies studied. No hemorrhage was observed.

WONTECH

02 Clinical Study of 532nm, 1064nm, 755nm

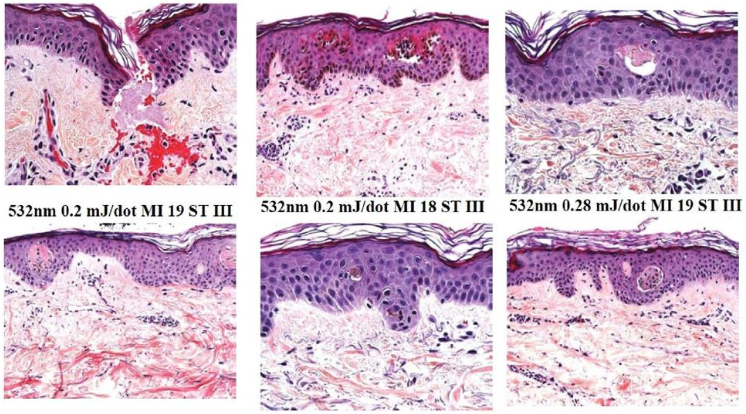


Fig. 2. Five hundred and thirty-two nanometer- focal areas of epidermal necrosis and areas of superficial dermal hemorrhage is seen in the lighter skin types MI 12–15 with the lower energies. As the energy increases and the MI increases focal epidermal vacuoles are observed with areas of dermal hemorrhage. In the more pigmented individual MI 24, 30, and 95, more vacuoles were observed which became larger and more numerous as the MI and energy increased. Fewer areas of dermal hemorrhage were seen in the darker skin types.

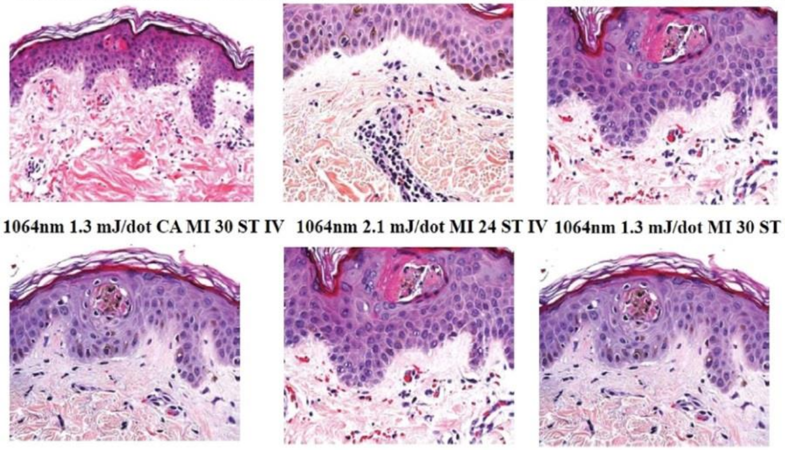


Fig. 3. One thousand and sixty-four nanometer- intra-epidermal vacuoles accompanied by focal areas of dermal hemorrhage were observed were routinely observed across the fluences and skin types studied. In the darker skin types the vacuoles and areas of damage became larger and more superficially situated. Focal areas of hemorrhage were appreciated.

Histology ; 532nm

Histology ; 1064nm

WONTECH

WONTECH Co., Ltd.

Headquarters
64 Techno 8-ro, Yuseong-gu, Daejeon, Korea

Pangyo-Branch
22, Daewangpangyo-ro 712 beon-gil, Seongnam-si, Gyeonggi-do, Korea

TEL. 1670-1450
FAX. 070-7882-8658
E-mail. wtlaser@wtlaser.com