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Basic principles of laser tattoo removal

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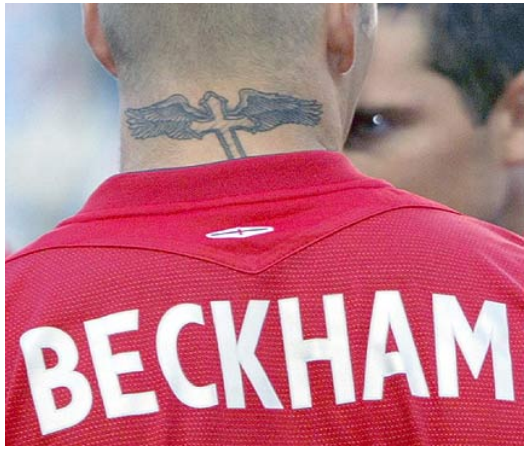
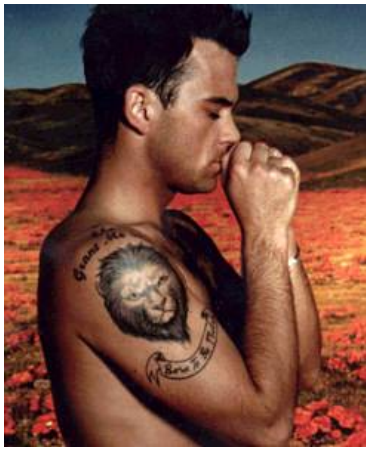
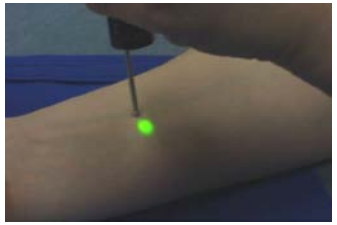
Removal of Tattoos with Lasers

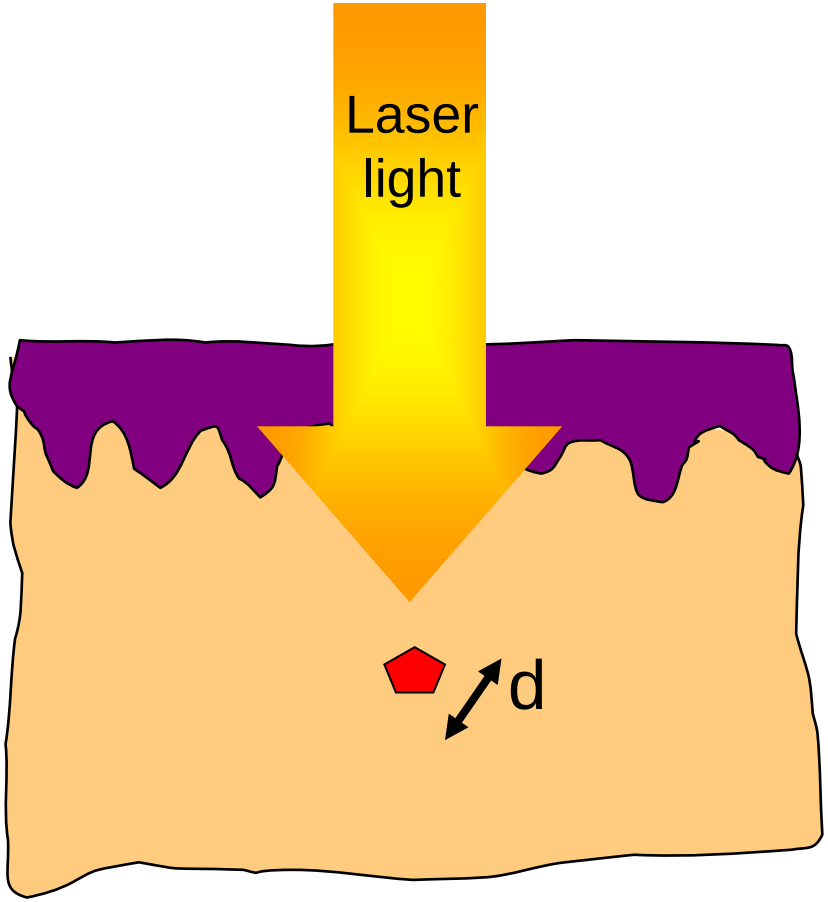




Removal of Tattoos with Lasers – so far

No destruction of the whole tissue…





Selective Photothermolysis

- appropriate wavelength

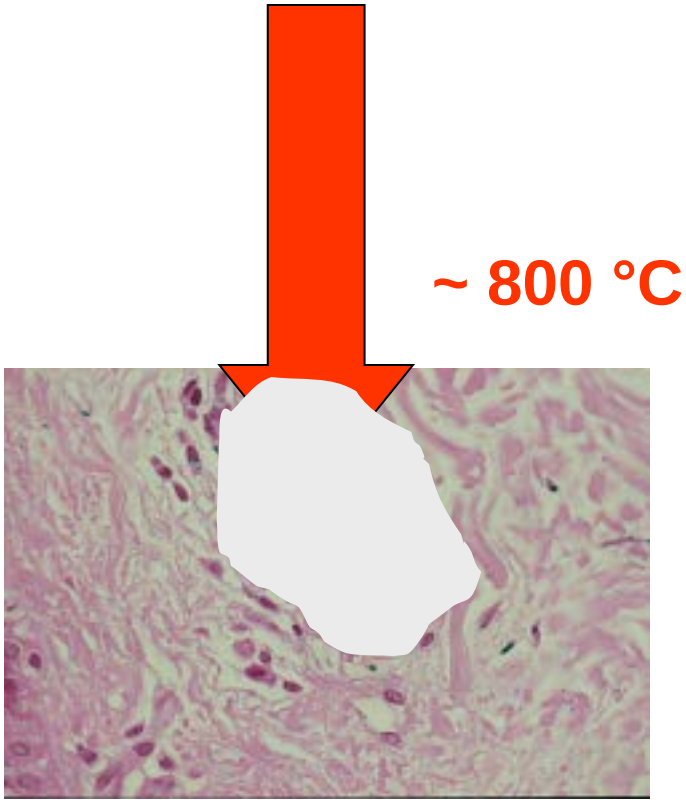
  that is selectively absorbed in pigments
- sufficient energy

  to heat up the pigment
- appropriate pulse duration

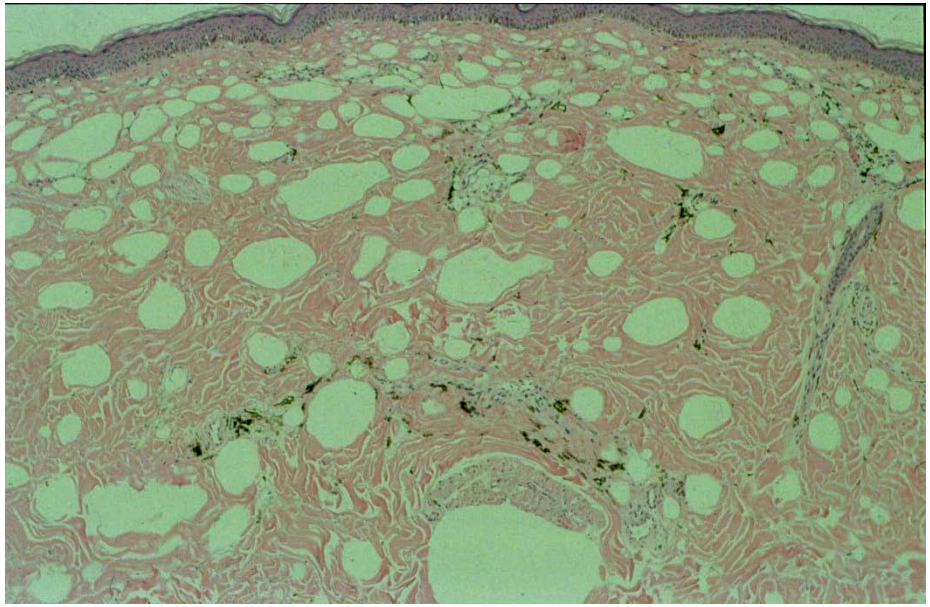
  to heat the pigment only

Removal of Tattoos with Lasers – so far

ultrashort pulse duration	10 ns
extremely high intensity	10^9 W/cm²



ruby laser (694 nm)



Removal of Tattoos with Lasers – so far

Ruby laser

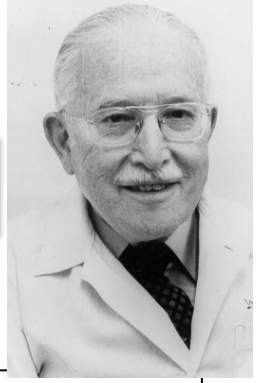
before laser therapy

5 min
after laser therapy

4 weeks
after laser therapy

Removal of Tattoos with Lasers, 1965

Leon Goldman, J Invest Dermatol. 1965, 44:69-71



Preliminary and Short Report

RADIATION FROM A Q-SWITCHED RUBY LASER

EFFECT OF REPEATED IMPACTS OF POWER OUTPUT OF 10 MEGAWATTS ON A TATTOO OF MAN*

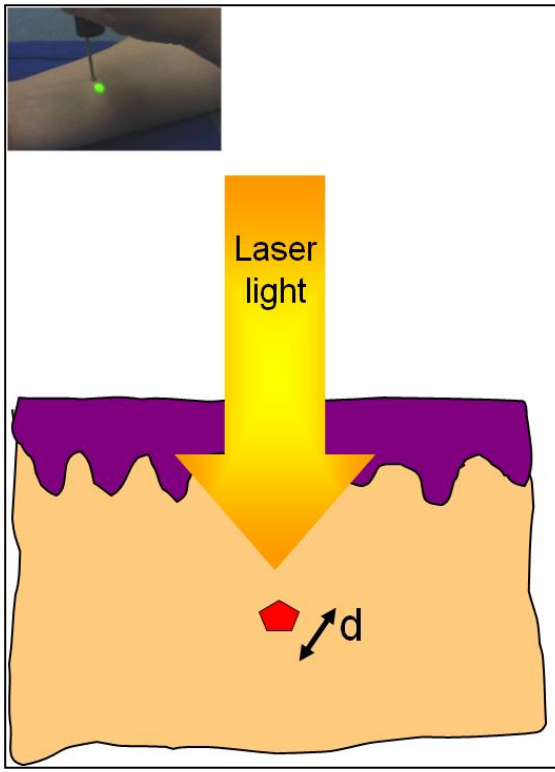
not in the white skin. As yet, the mechanism of this change in the skin reactions of the tattoo to Q-switched ruby lasers is not known, but the differences were probably not due entirely to thermal factors.

Q-switching produces laser impacts of high peak power outputs with the duration of the impact in the order of nanoseconds. There is considerable interest in the type of tissue change produced by

approximately 0.9 cm², while the focused beam area was approximately 0.01 cm². Impacts were made directly on the dark tattoo and on the edge of the tattoo. Control impacts were made on ad-

Removal of Tattoos with Lasers, 1965 - so far

But is that the correct explanation ?



Selective

Photothermolysis

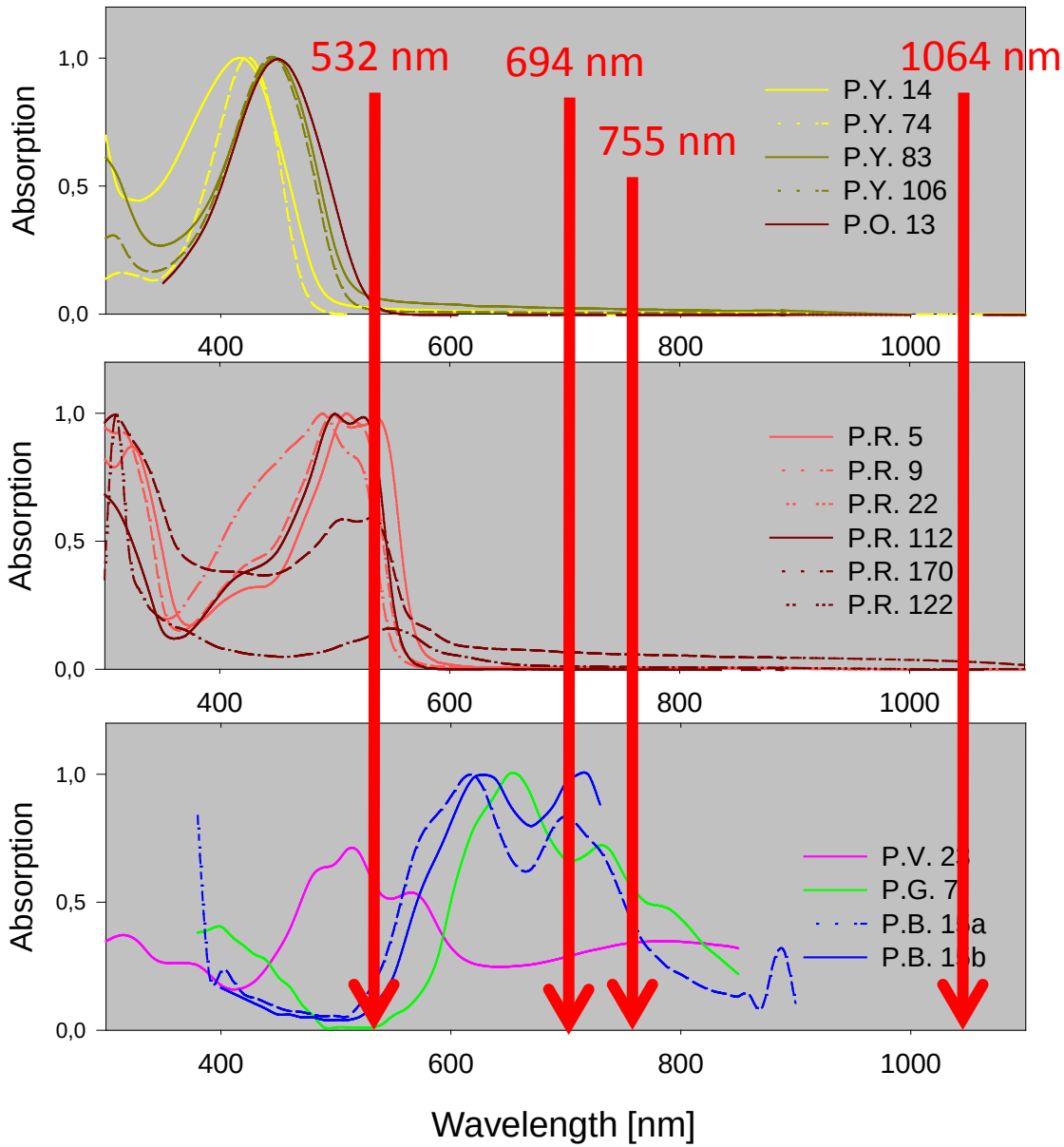
- appropriate wavelength

  that is selectively absorbed in pigments
- sufficient energy

  to heat up the pigment
- appropriate pulse duration

  to heat the pigment only

One doubt - Appropriate wavelength



Removal of Tattoos with Lasers
Old + new ideas

Endogenous target, Tissue coagulation or vaporisation

- Normal light absorption in endogenous targets like water, hemoglobin, melanin
- biological, water-containing material
- Normal light intensities
  - e.g. blood vessel coagulation with pulsed dye laser
  - 6 J/cm² (1 ms pulse duration) $6 \cdot 10^3$ W/cm²
- Destruction of tissue: removal by usual endogenous mechanisms

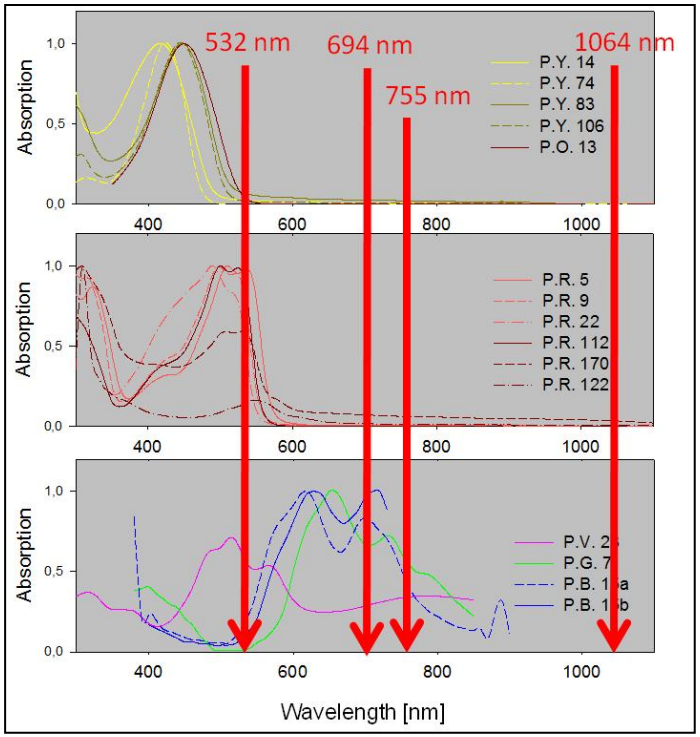
Removal of Tattoos with Lasers – old + new ideas

Exogenous target, Pigment Particle destruction

- Normal (?) light absorption in exogenous target: pigment particle
- Solid state material with complex chemical and physical properties
- High light intensities
  - Tattoo removal with Q-switched laser
  - 3 - 5 J/cm² (0.5 - 20 ns pulse duration) ~10^9 - 10^{10} W/cm²
- Destruction of exogenous solid state material:
  - unclear removal via lymphatic or blood vessel system
  - re-agglomeration of fragmented particles possible
  - and others

Removal of Tattoos with Lasers – old + new ideas

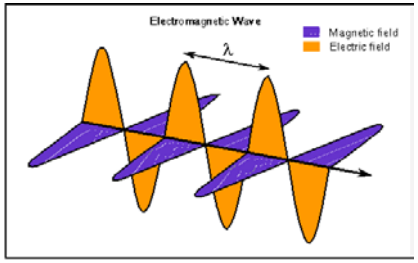
Normal absorption ?



What might happen at high intensities ?

Linear and non-linear optics

Light is an electrical field (E) or a particle (photon)



Linear optics:

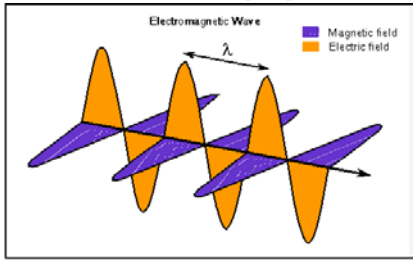
- small intensities, therefore photons do not interact with each other
- Interaction with material ~ E
  - 1 – Photon absorption

Nonlinear optics:

- high intensities (laser), photons can interact with each other
- Interaction with material ~ E or E^2 or E^3 or E^4 or …
- Yielding various effects
  - Frequency doubling, tripling
  - Frequency mixing
  - 2-Photon absorption
  - Plasma generation (optical breakdown)
  - etc

Linear and non-linear optics

Light is an electrical field (E) or a particle (photon)



Linear optics:

- small intensities and photons do not interact with each other
- Interaction with material ~ E
  - 1 – Photon absorption

Nonlinear optics:

- high intensities (laser) and photons can interact with each other
- Interaction with material ~ E or E^2 or E^3 or E^4 or …
- Yielding various effects
  - Frequency doubling, tripling
  - Frequency mixing
  - 2-Photon absorption
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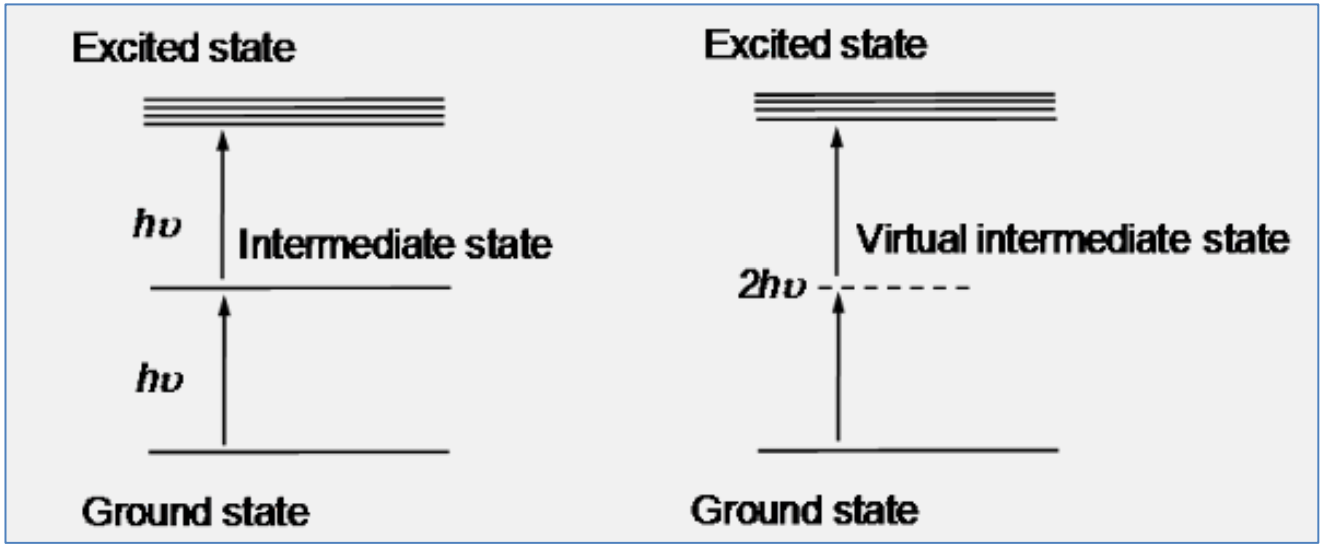
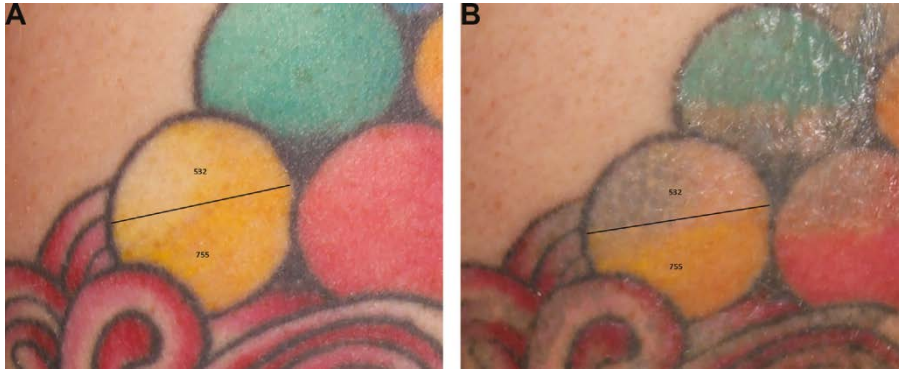
  - etc

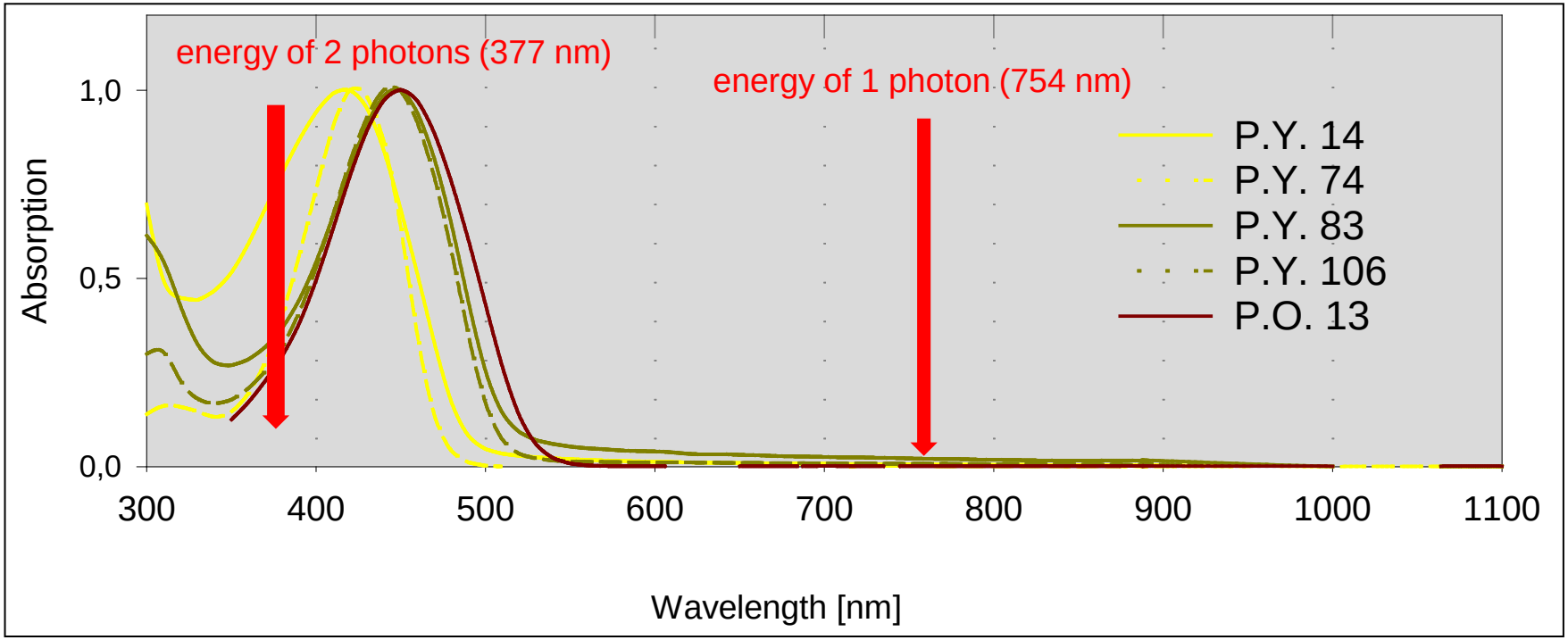
Possible non-linear effects: 2 – Photon absorption

For instance:
2 Photons with 1064 nm are absorbed like
1 Photon with 532 nm



Possible non-linear effects: 2 – Photon absorption





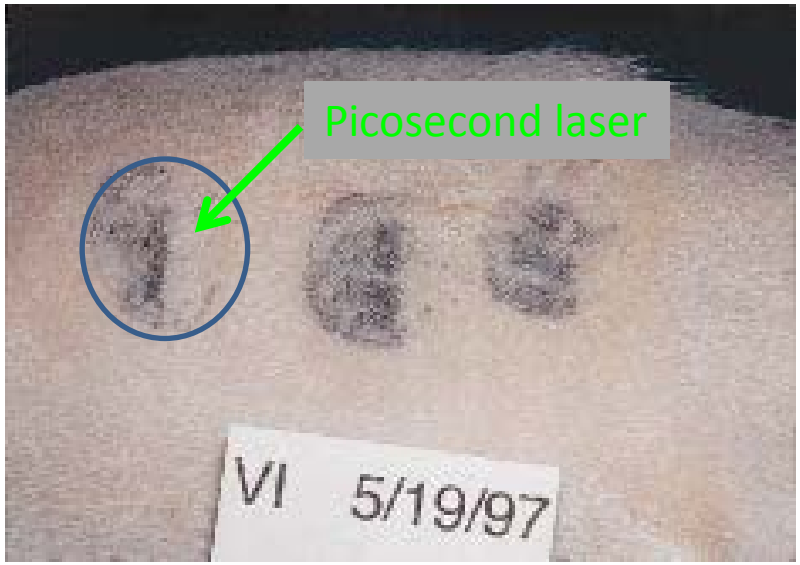
Possible non-linear effects: optical break down

A clinical and histologic prospective controlled comparative study of the picosecond titanium:sapphire (795 nm) laser versus the Q-switched alexandrite (752 nm) laser for removing tattoo pigment

Robert M. Herd, MD,[a] Maria Beatrice Alora, MD,[a] Bruce Smoller, MD,[b]
Kenneth A. Arndt, MD,[a] and Jeffrey S. Dover, MD, FRCPC[a]
Boston, Massachusetts, and Little Rock, Arkansas

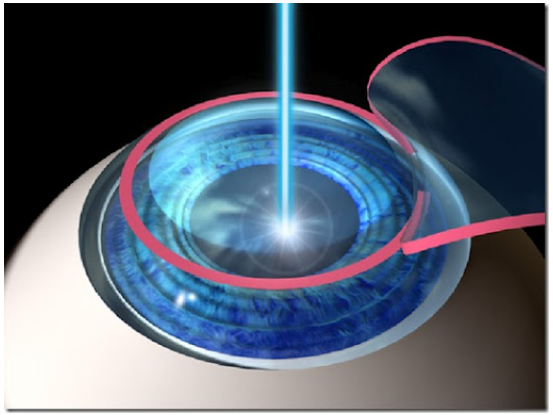
J Am Acad Dermatol 1999;40:603-6

black india ink



Possible non-linear effects: optical break down

well-known effect in ophthalmology: cornea surgery with focused laser beams



optical break down* in water (plasma and bubble formation) ~ 10^{11} W/cm²

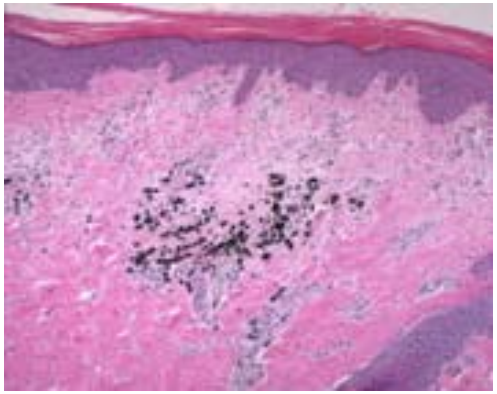
wavelength	pulse duration	threshold intensity for break down
532 nm	60 ps	$2.8 \cdot 10^{11}$ W/cm²
750 nm	76 ns	$0.2 \cdot 10^{11}$ W/cm²
1064 nm	6 ns	$0.5 \cdot 10^{11}$ W/cm²
1064 nm	60 ps	$3.7 \cdot 10^{11}$ W/cm²

Home » PicoWay » SYSTEM SPEZIFIKATIONEN

PicoWay Specifications

Laser Type	Nd:YAG Frequency	Doubled Nd:YAG
Wavelengths	1064 nm	532 nm
Maximum Energy	400 mJ	200 mJ
Pulse Duration	450 ps	375 ps
Peak Power	0.90 Gigawatts	0.53 Gigawatts
Spot Sizes	2, 3, 4, 5, 6, 7, 8, 9, 10 mm	
Repetition Rate	Single, 1, 2, 3, 4, 5, 10 Hz	
Delivery System	Articulated arm with zoom handpiece	
Warm Up Time	2 minutes	
User Interface	Touchscreen with GUI	
Size	42" H x 18" W x 27" D	

~ $0.3 \cdot 10^{11}$ W/cm²



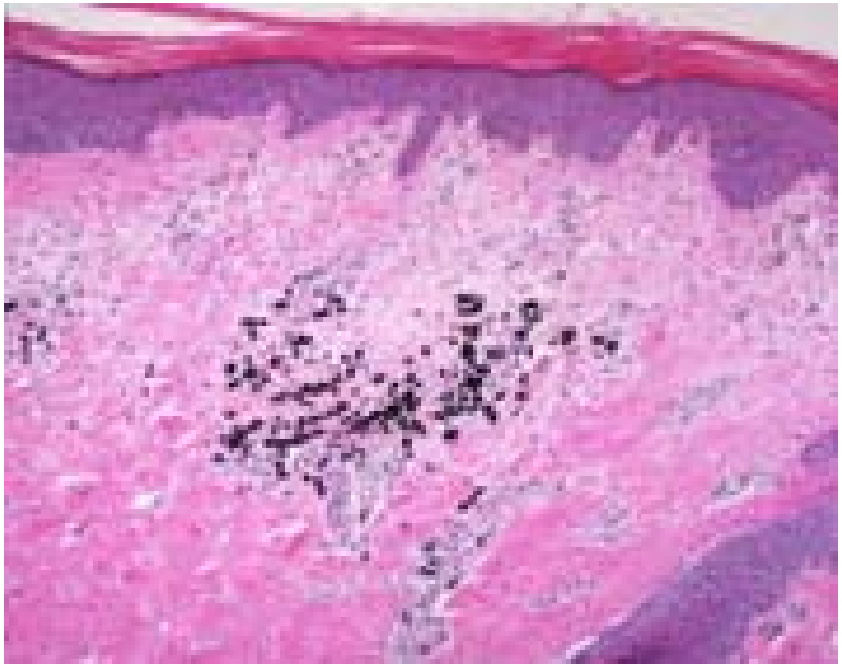
Izikson et al, Lasers Surg Med 42:640–646 (2010)

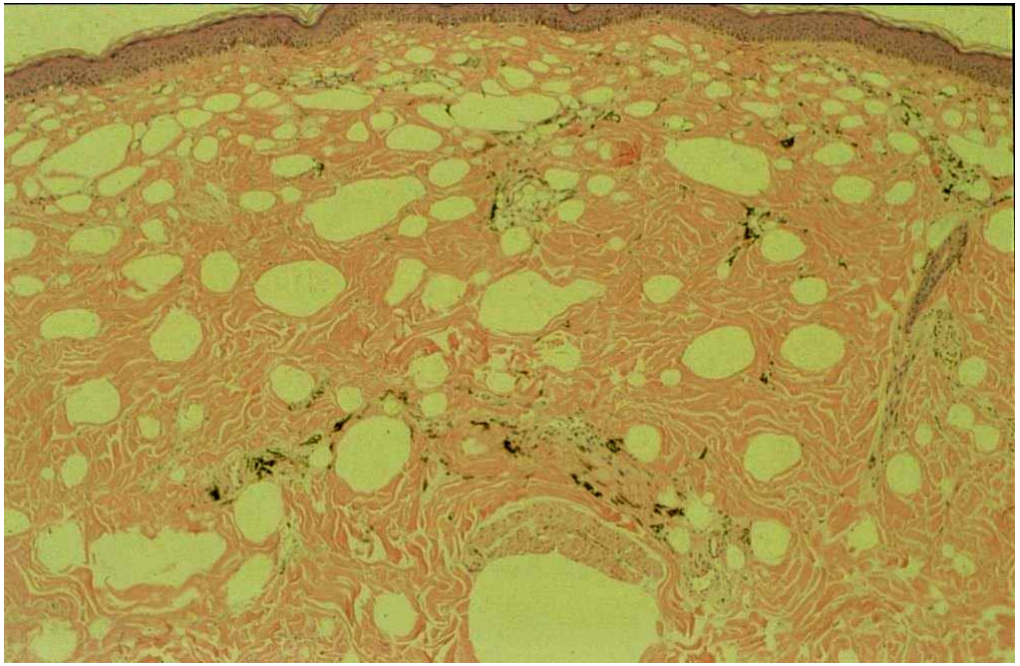
*Vogel et al, Appl. Phys. B 68, 271–280 (1999).

Removal of Tattoos with Lasers

2 – Photon absorption ?

Bubble formation via optical breakdown ?

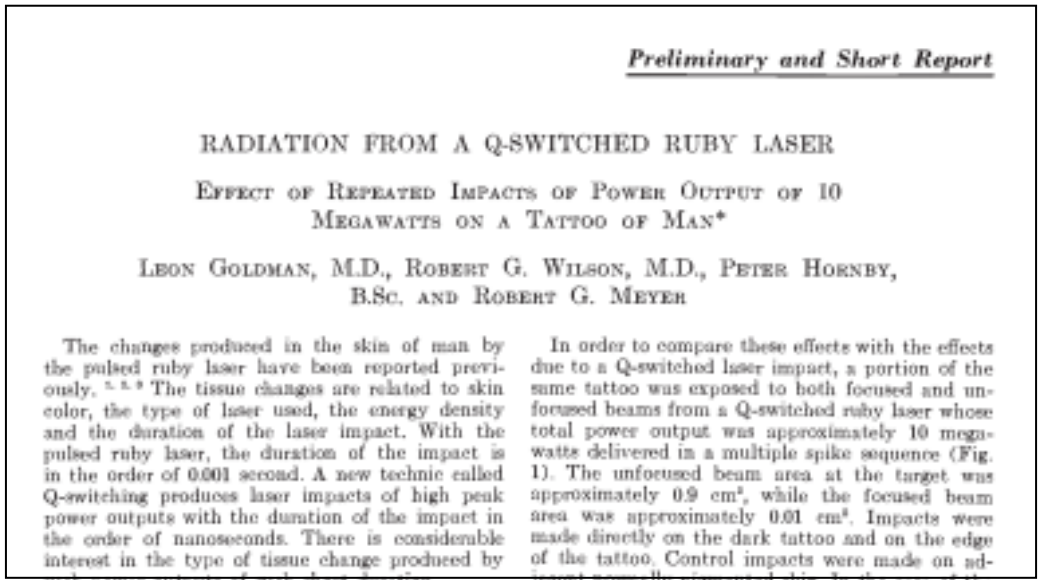




histology, 5 min after laser treatment

Conclusion

- Many mechanisms involved in laser tattoo removal
- Many mechanisms are still unclear
- We need more research
- Optimization of laser treatment requires more detailed understanding of the underlying mechanisms



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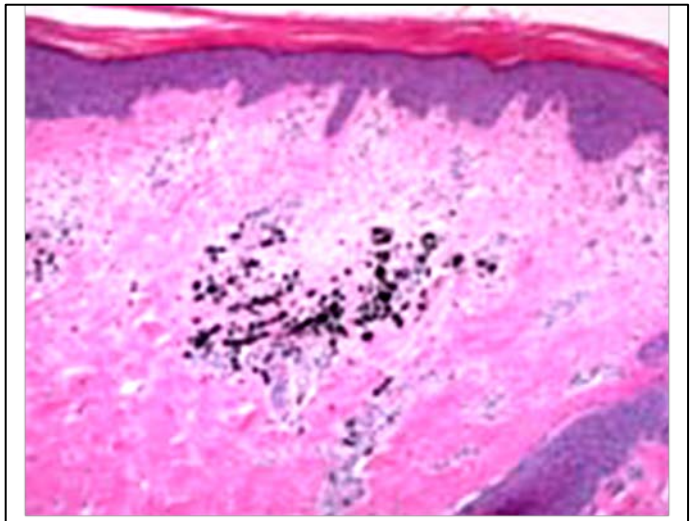
EFFECT OF REPEATED IMPACTS OF POWER OUTPUT OF 10 MEGAWATTS ON A TATTOO OF MAN*

LEON GOLDMAN, M.D., ROBERT G. WILSON, M.D., PETER HORNBY, B.Sc. AND ROBERT G. MEYER

The changes produced in the skin of man by the pulsed ruby laser have been reported previously.[2,3,9] The tissue changes are related to skin color, the type of laser used, the energy density and the duration of the laser impact. With the pulsed ruby laser, the duration of the impact is in the order of 0.001 second. A new technic called Q-switching produces laser impacts of high peak power outputs with the duration of the impact in the order of nanoseconds. There is considerable interest in the type of tissue change produced by

In order to compare these effects with the effects due to a Q-switched laser impact, a portion of the same tattoo was exposed to both focused and unfocused beams from a Q-switched ruby laser whose total power output was approximately 10 megawatts delivered in a multiple spike sequence (Fig. 1). The unfocused beam area at the target was approximately 0.9 cm^2, while the focused beam area was approximately 0.01 cm^2. Impacts were made directly on the dark tattoo and on the edge of the tattoo. Control impacts were made on ad-



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