



# Lasers in dermatology

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# Objective?

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- ▶ understand basic laser physics
- ▶ patient's expectations
- ▶ avoid complications



# Interactions of substance and laser light


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- **photochemical reactions**
- **photoablation**
  - brake of molecular bindings
  - precise cutting and ablation with excimer laser
  - ophthalmology, angioplasty
  - skin resurfacing, peeling, benign skin tumors
- **mechanical, photoacoustic**
  - Q-switched lasers, high fluence and ultrashort pulse
  - nephrolith braking
  - dermatology: pigmented lesions, tattoo removal
- **photothermal**



# Interactions of substance and laser light photothermal effect

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light energy            thermal energy

37°C - no damage

40-45°C – edema, enzyme induction

60°C – protein denaturation, coagulation

80°C – collagen denaturation, membrane damage

100°C - boiling, exsiccation

150°C – carbonization

300°C - vaporization

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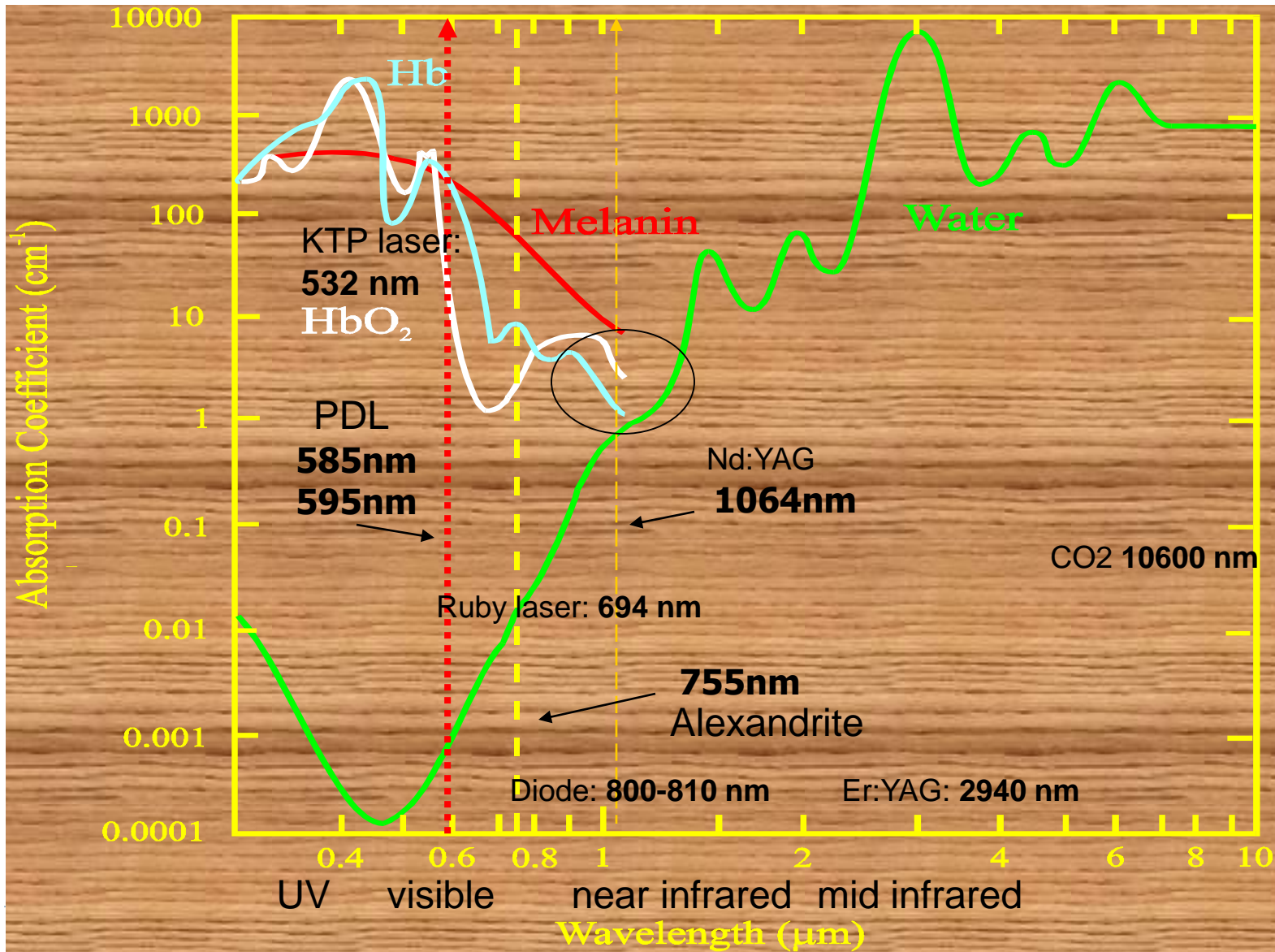
# Thermal damage is influenced:

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- ▶ amount of chromophores (light absorbing structures, e.g. haemoglobin, melanin, water)
- ▶ duration of the impulse (exposure time, pulse duration, pulse width)
- ▶ fluence
- ▶ spot size



# The four major chromophores in skin



# Lasers in dermatology

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Generally as higher the wavelength, deeper the effect

- ▶ Argon laser: 488 nm
  - ▶ KTP laser: 532 nm
  - ▶ PDL (pulsed dye): 585 nm
  - ▶ Ruby laser: 694 nm
  - ▶ Alexandrite: 755 nm → hair removal, pigmented lesion
  - ▶ Diode: 800-810 nm
  - ▶ Nd:YAG: 1064 nm → deeper vessels, HR, photorejuvenation
  - ▶ Er:YAG: 2940 nm → peeling (ablative)
  - ▶ CO<sub>2</sub>: 10600 nm → vaporization (surgery)
  - ▶ Q-switched lasers (ultra short pulse): tattoo, pigment lesions
- } thin vessels



# What is Laser?

- Light
- Amplification by
- Stimulated
- Emission of
- Radiation

Stimulation of a substance results in light emission when its molecules return to stable state

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# LASER light

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- ▶ a given stimulated substance can produce light with a specific wavelength
- ▶ Monochromatic (one wavelength)
- ▶ Coherent (photons are in the same phase)
- ▶ Collimated (waves are parallel)



# IPL (Intense pulsed light)

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- ▶ Not a laser!
- ▶ Wide spectrum
- ▶ Filters
- ▶ HR: hair removal 600-950 nm
- ▶ PR: photorejuvenation 530-750 nm
- ▶ PL: pigmented lesions 400-720 nm
- ▶ VL: vascular lesions 555-950 nm
- ▶ Handpiece is in contact with skin surface, contact gel required



## IPL Systems

## Lasers

Non-monochromatic (A band of wavelengths)

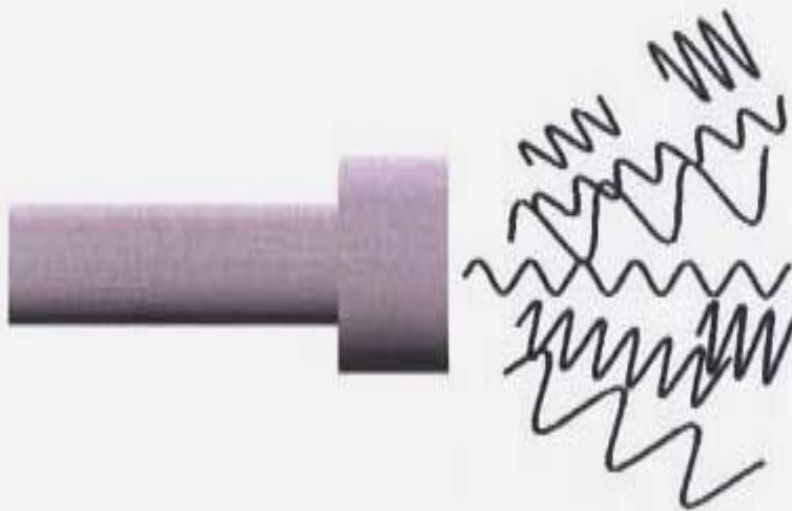
Monochromatic (Only one wavelength)

Non-Coherent (Waves are not in phase)

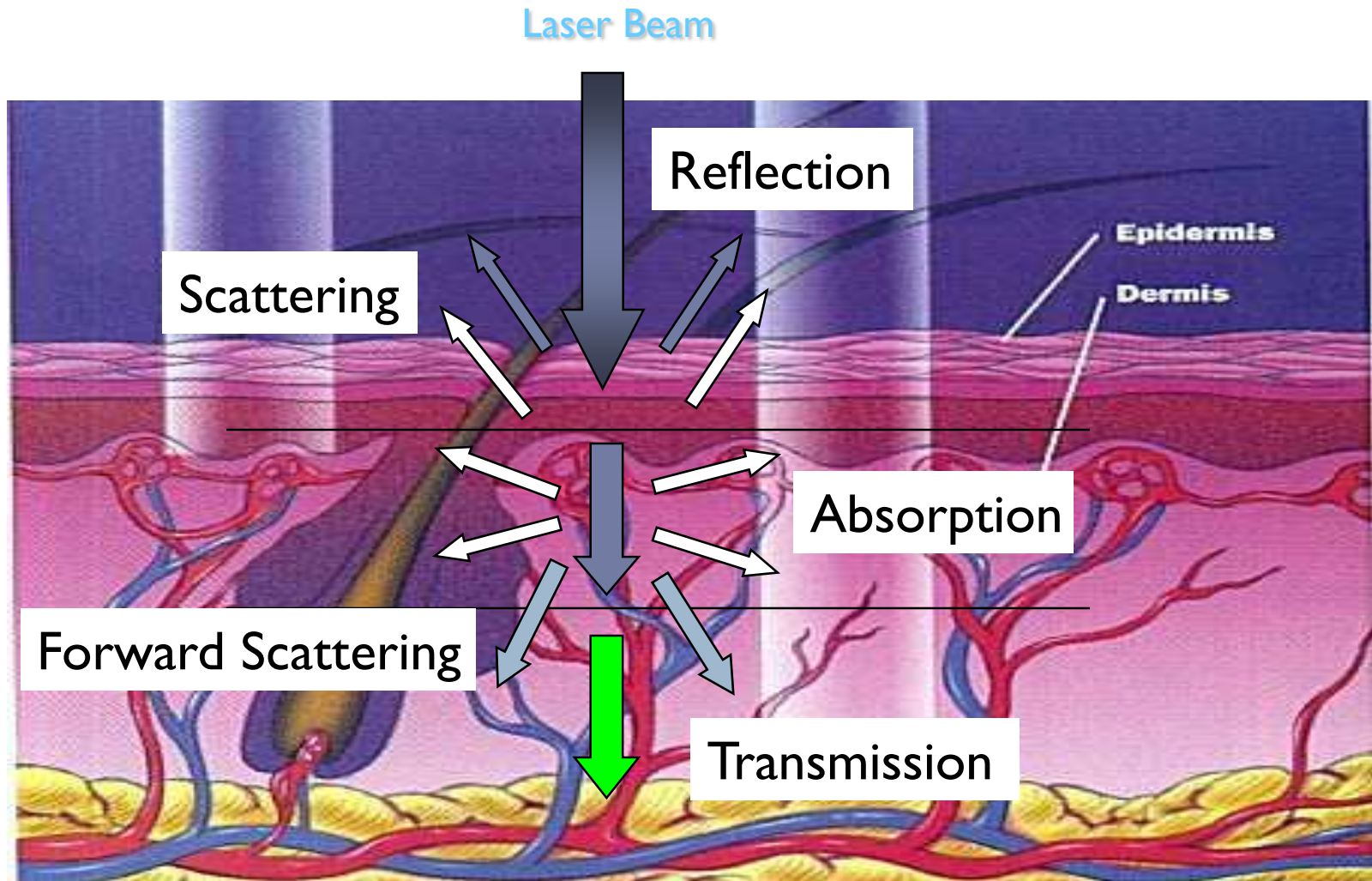
Coherent (Waves are always in phase)

Defocused light

Parallel light (Collimated)



# Laser tissue interactions

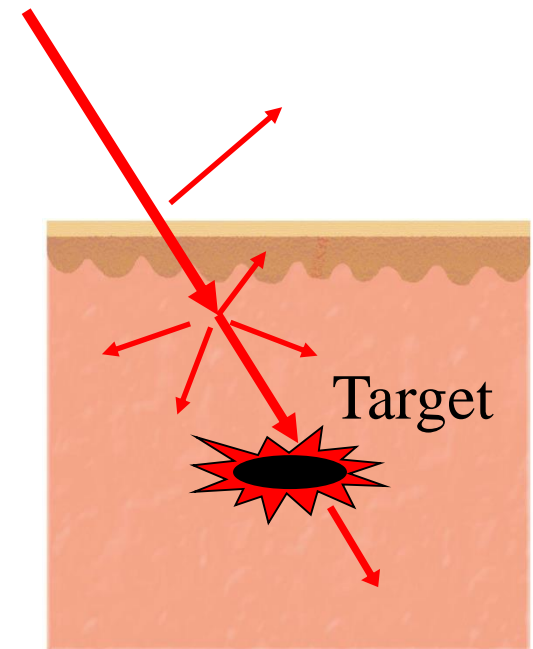


# Selective laser absorption

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## Desired Response:

1. Sufficient light reaches target
2. Light absorbed by target
3. Absorbed light converted to heat
4. Temperature rise in target sufficient to provide desired damage
5. Minimal heating of surrounding tissue



# Selective photothermolysis

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- ▶ Controlled destruction of a targeted lesion without significant thermal damage to surrounding normal tissue
- ▶ A proper wavelength to destroy selectively the target
- ▶ Shorter pulse width than the chromophores thermal relaxation time



# Thermal Relaxation Time (TRT)

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- ▶ The time necessary for the target to cool down 50%, through the transfer of its heat to surrounding tissue via thermal diffusion.
- ▶ To destroy a target the thermal relaxation time of the target must be considered.
- ▶ Smaller objects cool off faster than larger objects! This is important in understanding the role of pulse duration.



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➤ Laser hair removal





# Hair removal

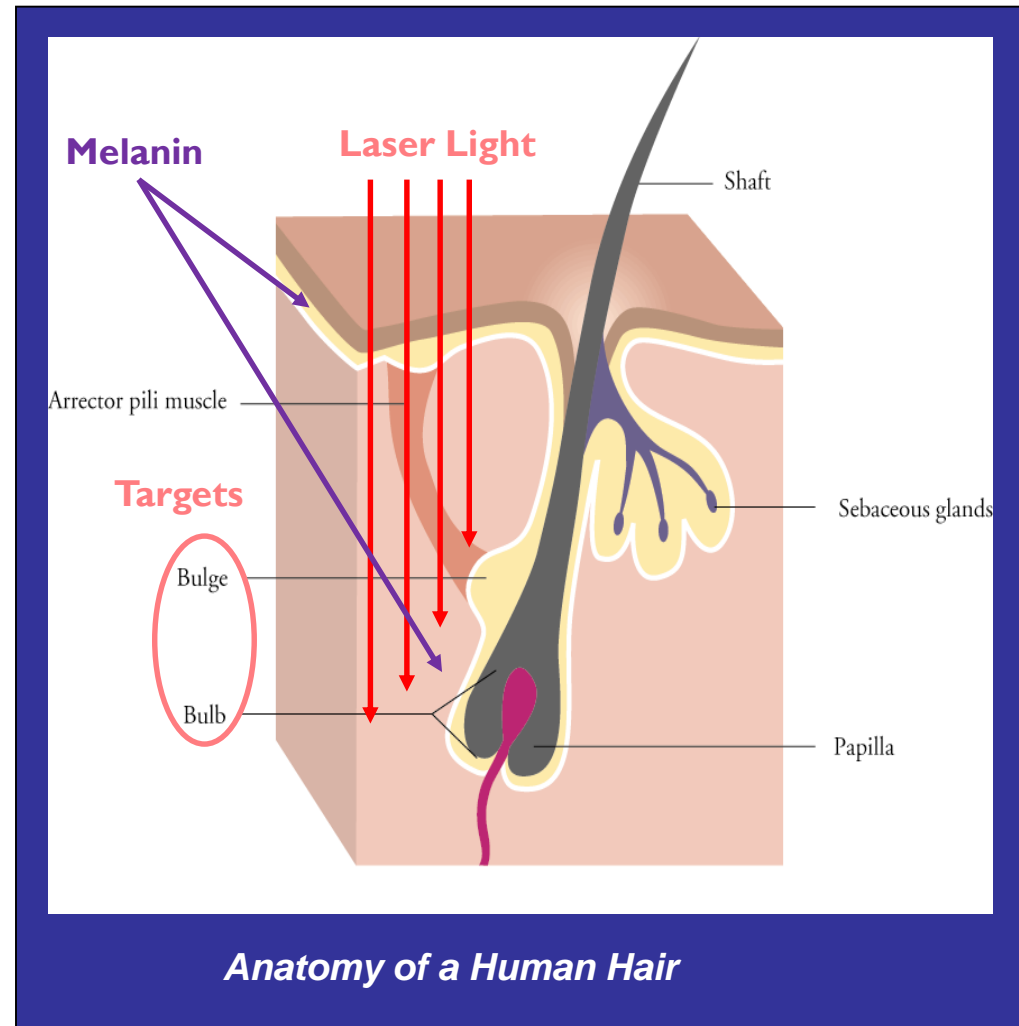
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- Most often used systems: alexandrite, Nd:YAG, IPL
- target: the hair bulb and a stem cell area (near adhesion of m. arrector pili)
- result depends: type of laser, color and thickness of the hair shaft, skin pigmentation (tanning or skin type)
- ideal patient: light skin, dark hair
- hair shaft in anagen phasis, repeated treatments
- 5-7 treatment sessions
- maintaining sessions (1-2/year )

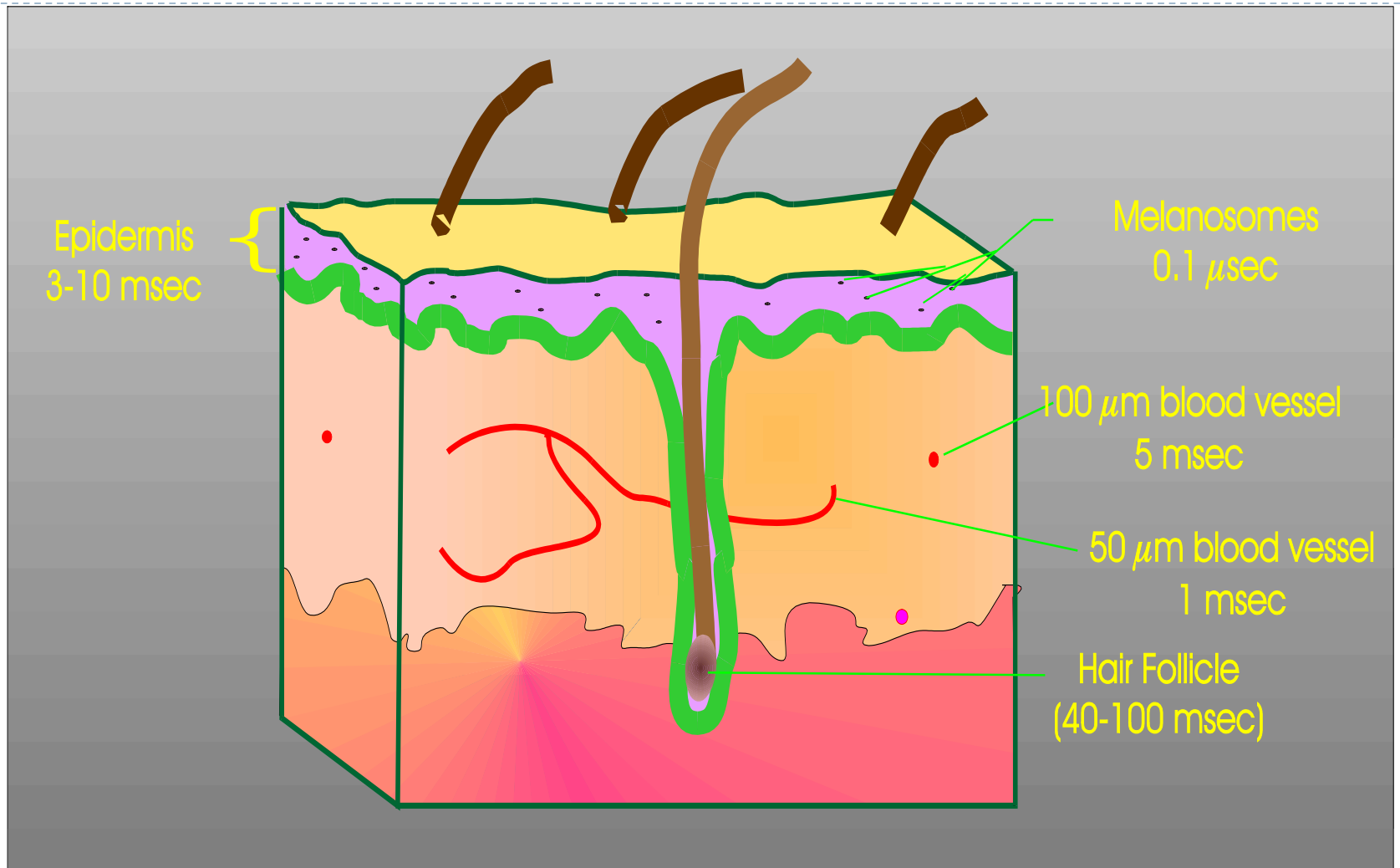


# Challenge of laser hair removal

- melanin is in the epidermis and hair
- the more melanin, the more heat: be careful with tanned or dark skin
- epidermal safety determined by amount of melanin and laser parameters (wavelength, fluence),
- epidermal cooling increases **safety**
- darker skin: test treatment

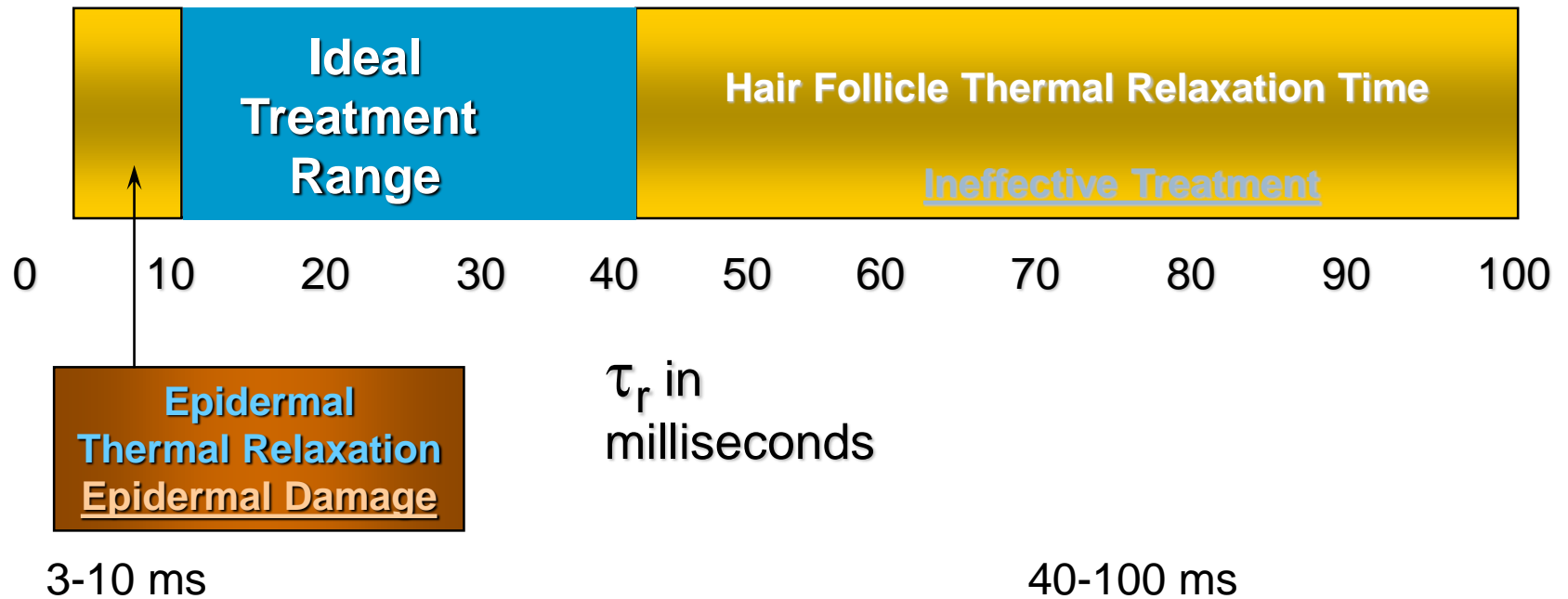


# Thermal Relaxation Times



# Ideal Range for Laser Hair Removal

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# Ideal hair reduction lasers

Skin Type	WL	PD	Cooling
I – IV	755nm alexandrite or IPL	10 – 40 msec	Cold Air
IV – VI	1064nm Nd:YAG	10 – 40 msec	Contact Cooling Cold Air

New method Nd:YAG hair removal

- shorter pulses: 0.6-1.6 ms pulse duration
- repeated passes/3x (epidermis can cool down, safer in dark skin people)

# ➤ Vascular Lesions



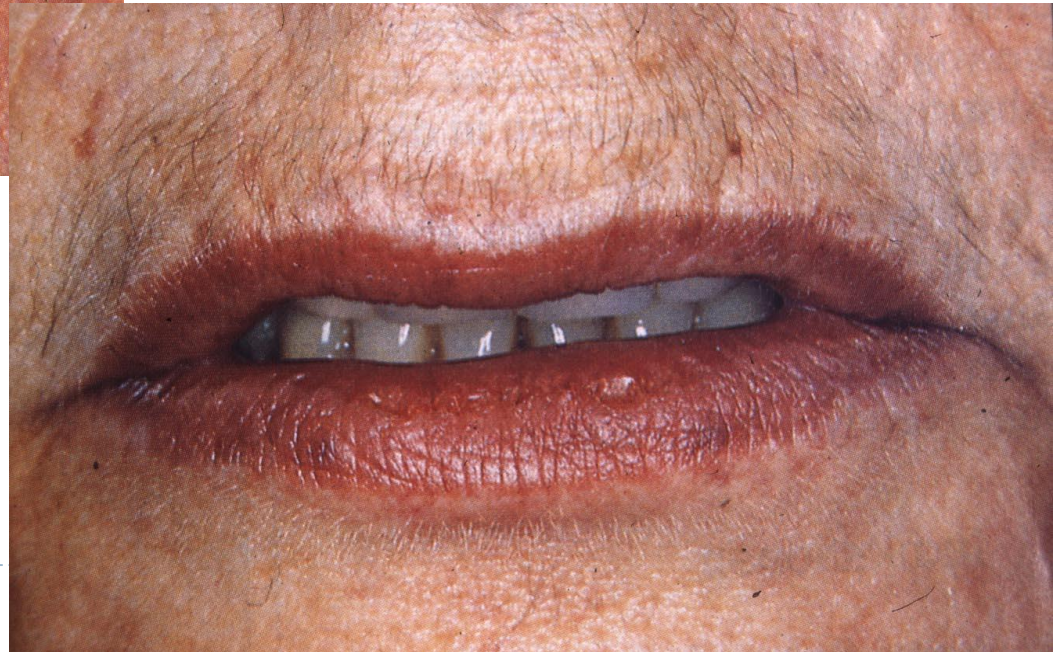
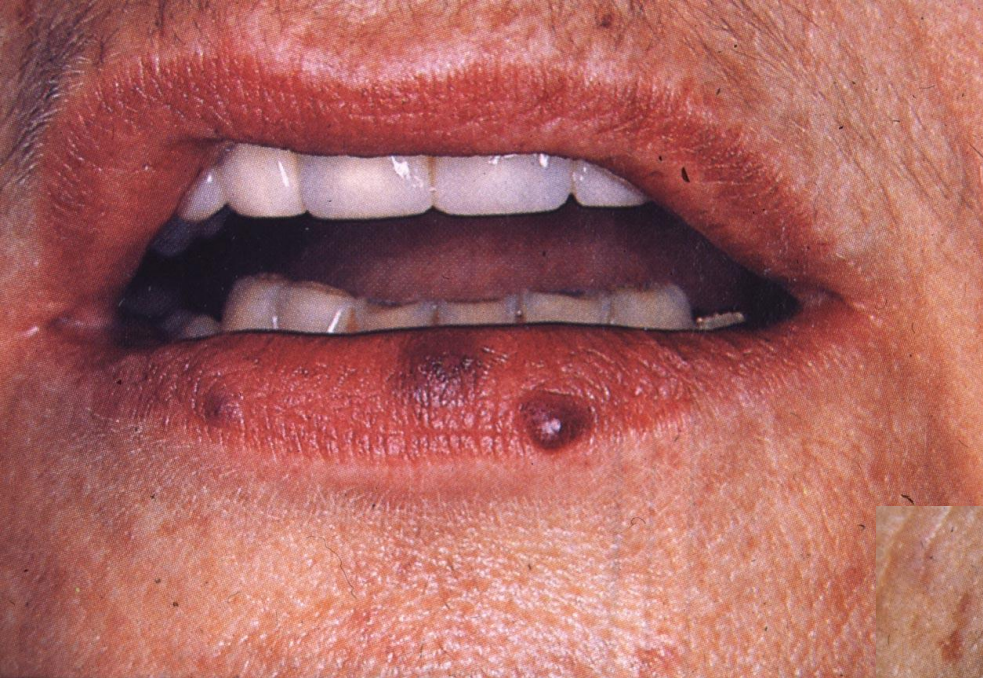
• superficial vascular lesions → dye lasers  
585- 590-595-600 nm

• deep vascular lesions → Nd:YAG  
1064nm



# Angiomas on the lower lip: Nd:YAG laser treatment

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# 12 yo male patient, angiokeratoma

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1 month after 1st session



Nd:YAG 1x, 150 J/cm<sup>2</sup>, 4 mm spot, 20 ms

# Treatment result

1st treatment: Nd:YAG, 150 J/cm<sup>2</sup>, 4 mm spot, 20 ms

2nd treatment: Nd:YAG, 170 J/cm<sup>2</sup>, 4 mm spot, 20 ms

3rd treatment: PDL 13 J/cm<sup>2</sup>, 7 mm spot, 0,5 ms



2018.02.03.



2018.04.07.



2018.09.08



# Spider angioma: treatment with Nd:YAG laser

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# Nd:YAG treatment of benign vascular tumors

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- ▶ 1064 nm
- ▶ appropriate absorption in haemoglobin
- ▶ deep penetration, suitable to treat deeper vessels/vascular lesions
- ▶ proper cooling (cold air) and right parameters (spot size, fluence, pulse duration) for safe treatment
- ▶ anesthesia if necessary (rare)



# Pulsed dye laser treatment of a cavernous angioma



# Treatment of vascular lesions in infancy and childhood

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- ▶ Differentiation of vascular tumors and malformations
- ▶ ISSVA classification of vascular anomalies 2014  
(International Society for the Study of Vascular Anomalies)
- ▶ In case of congenital and infantile hemangioma laser treatment is not first line therapy, but residual macular erythema and superficial teleangiectasia can be treated
- ▶ PDL is superior to other lasers
- ▶ naevus flammeus (port wine stain) laser treatment is recommended (early with PDL)

[Pediatrics, 2019.](#)

[From the American Academy of Pediatrics](#)

Clinical Practice Guideline for the Management of Infantile Hemangiomas

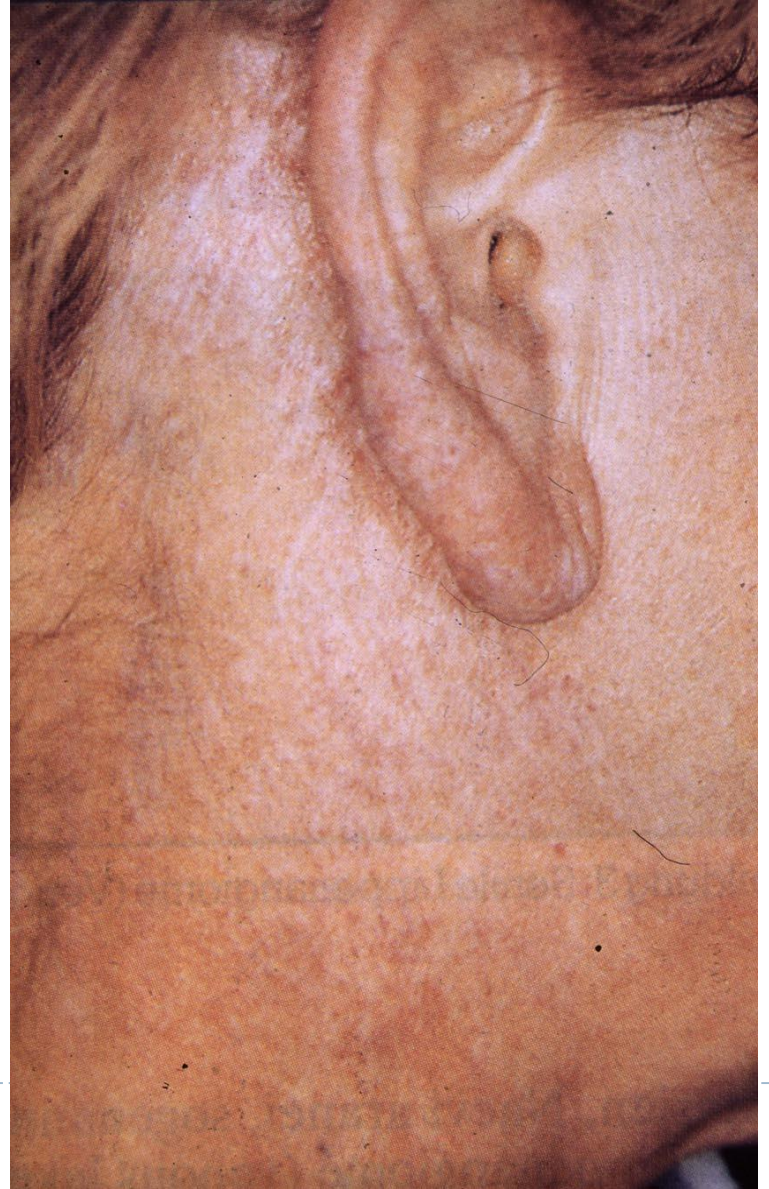
Daniel P. Krowchuk et al, SUBCOMMITTEE ON THE MANAGEMENT OF INFANTILE HE

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▶ Jeon et al; 2019; JAMA Dermatology

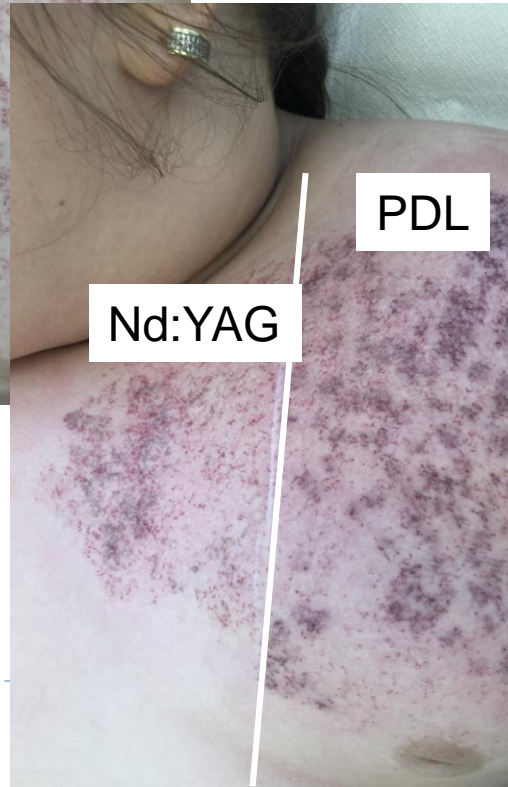
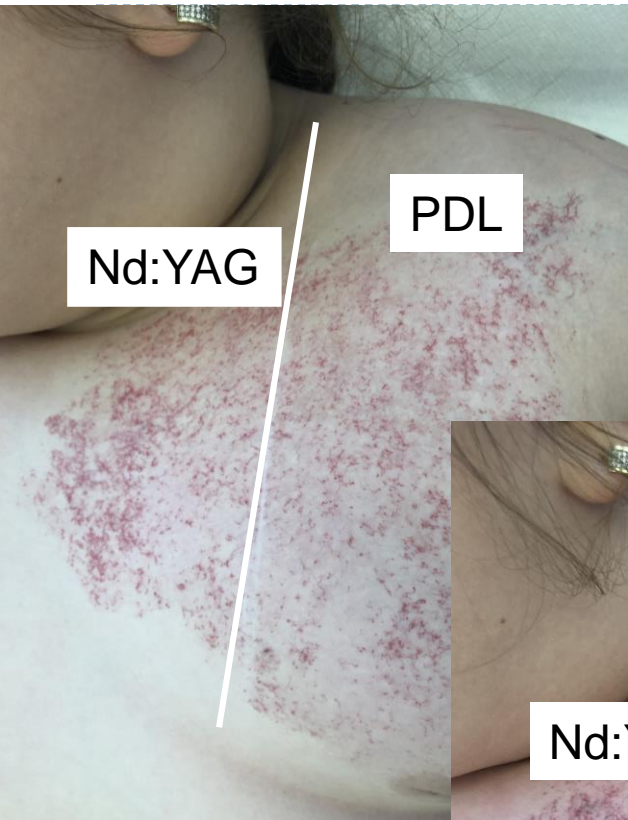
Pulsed Dye Laser Treatment of Port-Wine Stains in Infancy Without the Need for General Anes

# Treatment of a port wine stain with pulsed dye laser





# Port wine stain with teleangiectasia



# Teleangiectasia and unwanted veins

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- Telangiectasia occurs in approximately 30-40% of women and 5-10% in men
- Often desired treatment, most seek removal for cosmetic reasons
- Sclerotherapy is the treatment of choice for certain vessels
- Lasers are used alone or in conjunction with sclerotherapy for improved results



# Cynergy multiplex

## Improving Treatment Outcomes

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- ▶ By using both the **585 nm PDL** and **1064 nm Nd:YAG** wavelengths at the same session, that we can improve outcomes while minimizing adverse effect



# Cynergy multiplex

## Improving Treatment Outcomes

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- ▶ **How we can achieve synergistic effect?**
  - ▶ PDL: by heating blood 70° C, the Hb converts to metHb
  - ▶ MetHb has 3-5x greater absorption of the 1064nm wavelength, thus requiring less fluence to treat and coagulate the target



# Teleangiectasia treatment, Cynergy multiplex (PDL and Nd:YAG)



# Indications of Vascular Dye Laser

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- ▶ Vascular naevi
- ▶ Vasc. malformations
- ▶ Pyogenic granuloma
- ▶ Venous lakes
- ▶ Angiokeratoma
- ▶ Telangiectasia
- ▶ DLE
- ▶ Rosacea
- ▶ Keloids & Scars (existing & prophylactic)
- ▶ Warts
- ▶ Striae distinsae
- ▶ Acne & Post Acne scars
- ▶ Psoriasis



# Pyogenic granuloma

## PDL treatment 1x

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# Pulsed Dye Laser -How it works in acne?

## ▶ Photodynamic Activity

- ▶ *P. acnes* produces porphyrins
- ▶ PPIX has a peak at 585-nm
- ▶ PDL excites PPIX

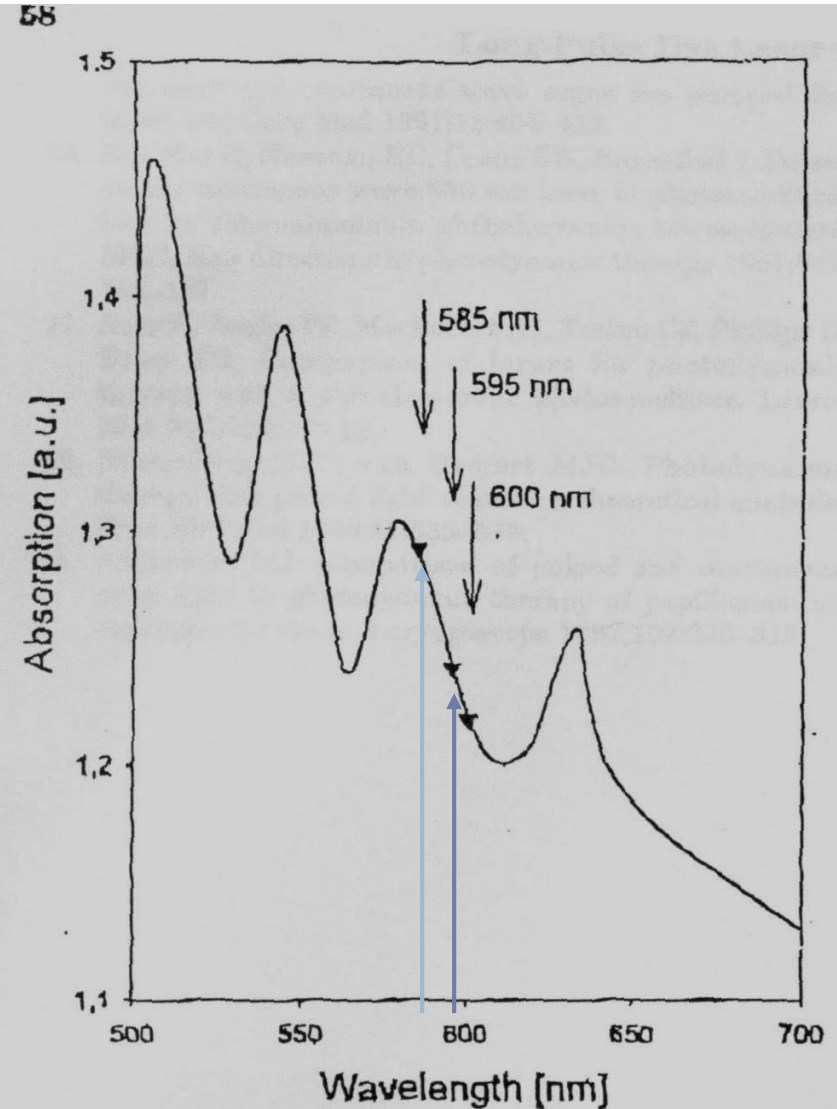


Fig. 5. Absorption bands of protoporphyrin IX in cell culture medium, markedly higher absorption of PpIX at a wavelength of 585 nm as compared to 595 nm and 600 nm.



# Pulsed dye laser (PDL) treatment of psoriasis

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- ▶ 585, 595 nm
- ▶ ablation of the superficial capillary bed of psoriatic lesions, reduction in the endothelial surface area and proliferation, reduction in T-lymphocyte infiltrate *Hacker, Rasmussen, Arch Dermatol, 1992*
- ▶ efficacy in plaque-type psoriasis *Erceg 2006, Bovenschen 2007*
- ▶ normalization of epidermal proliferation and keratinization *De Leeuw, 2009*
- ▶ **expression of VEGFR2, VEGFR3, E-selectin, IL23, TNF $\alpha$  decreased after 2 sessions of PDL** *Rácz et al, Lasers Surg Med 2010*



# Efficacy of PDL in Psoriasis

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before treatment

after 5 PDL treatments



PDL: 7mm spot size, 9 J/cm<sup>2</sup>, pulse duration: 0.5 msec

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# Efficacy of PDL and Multiplex laser in Psoriasis

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before treatment

after 5 treatments



PDL: 7 mm spot size, 12 J/cm<sup>2</sup>, pulse duration 0.5 ms

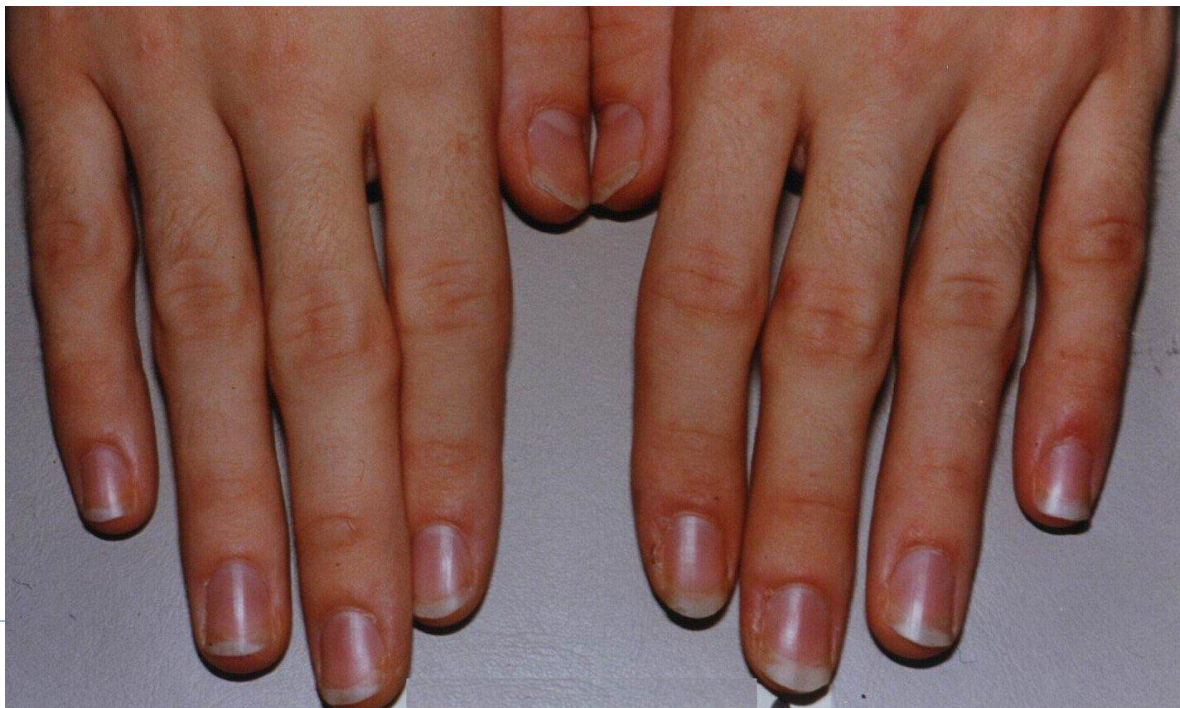
Multiplex: 7 mm spot size, **PDL/Nd:YAG** 12/50 J/cm<sup>2</sup>, pulse duration 10/15 ms



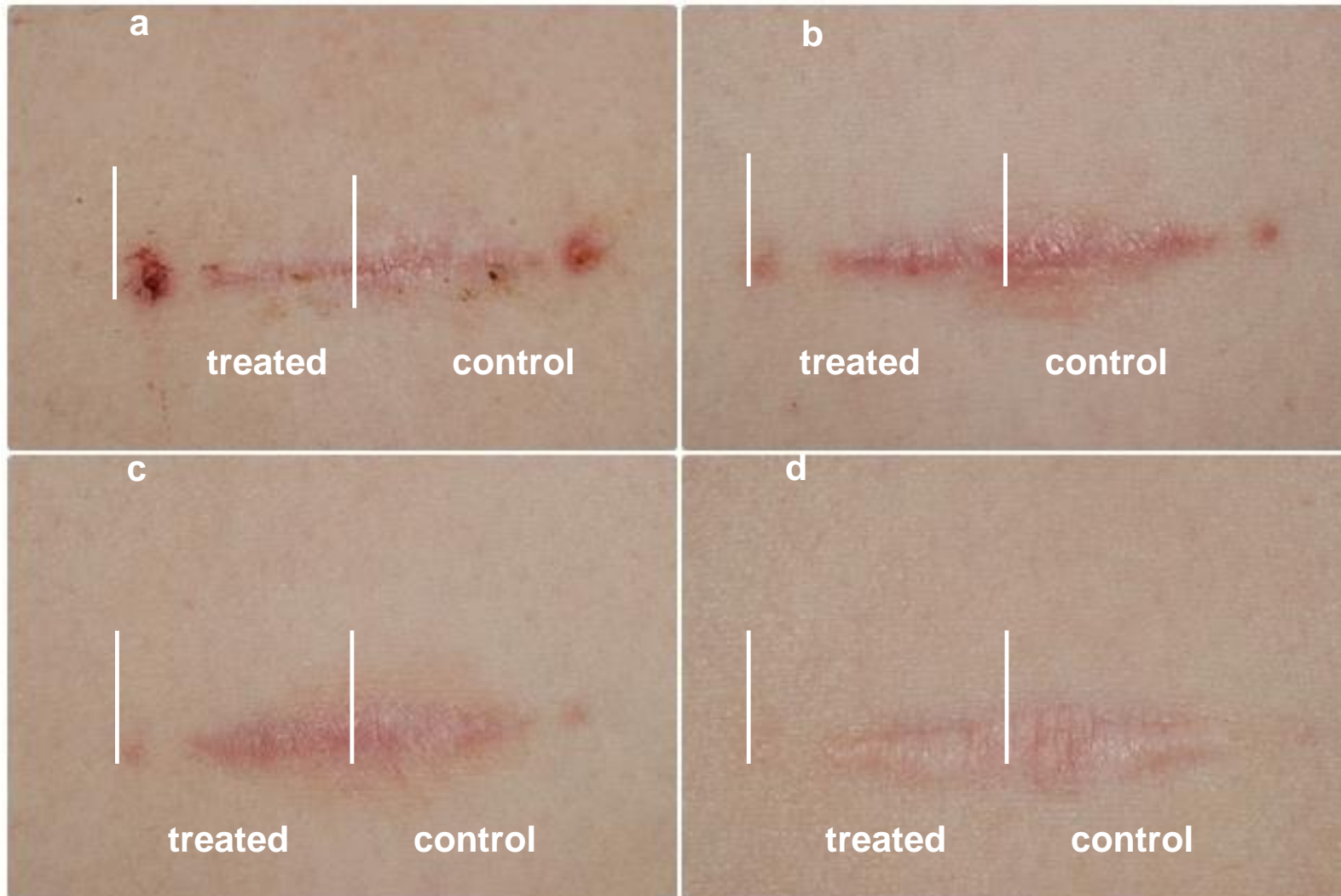
# PDL treatment of wart (2 sessions)

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# Multiplex PDL/Nd:YAG laser treatment of surgical scar



Vas K et al. Effects of the combined PDL/Nd:YAG laser on surgical scars: vascularity and collagen changes evaluated by in vivo confocal microscopy.

Biomed Res Int. 2014

a.) suture removal b.) one month after the first treatment c.) 2 months after the second treatment, d.) evaluation

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# Laser treatment of tattoo and pigmented lesions



# Q-Switch (ns) vs. Long Pulse (ms)

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- ▶ **Melanosome**
  - ▶ approximately  $1\ \mu\text{m}$  across
  - ▶ TRT approx 100's of ns
- ▶ **Q-switched Lasers (very short pulse duration in the ns range)**
  - ▶ Most likely rupture melanosomes (photoacoustic, photomechanical effect)
  - ▶ Macrophages carry away the crushed pigment
- ▶ **Long Pulse Light Sources**
  - ▶ Most likely damage cells with heat conducted from melanosomes





# Lasers for pigmented Lesions

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## Epidermal + Dermal

- |                           |        |
|---------------------------|--------|
| 1. Q-switched Ruby        | 694nm  |
| 2. Q-Switched Alexandrite | 755nm  |
| 3. Q-Switched Nd-YAG      | 1064nm |
| 4. fractional Er:YAG, CO2 |        |

## Epidermal

- |                   |       |
|-------------------|-------|
| 1. Pulsed Dye     | 510nm |
| 2. FD Nd-YAG      | 532nm |
| 3. LP Ruby        | 694nm |
| 4. LP Alexandrite | 755nm |

- 
- ▶ 5. IPL 400-720 nm

# Benign pigmented lesions: epidermal lesions

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- ▶ lentigines
- ▶ freckles
- ▶ café au lait macules
- ▶ naevus spilus
- ▶ seborrhoeic keratoses



# Benign pigmented lesions: dermal lesions

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- ▶ Naevus of Ota
- ▶ Naevus of Ito



# Benign pigmented lesions: dermal-epidermal lesions

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- ▶ melasma
- ▶ post-inflammatory hyperpigmentation
- ▶ Becker's naevus





▶ IPL treatment of ephelis (freckles)



Q-switched ruby laser treatment of PIH

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Q-switched  
ruby laser 3x



# Melanocytic naevus regrowth: pseudomelanoma





# Tattoos

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- ▶ Decorative
- ▶ Cosmetic
- ▶ Medical
- ▶ Traumatic
  
- ▶ Professional or amateur
  
- ▶ Different colors
  - ▶ Black 694 nm QS-ruby, 1064 nm QS-Nd:YAG
  - ▶ Blue 694 nm QS-ruby
  - ▶ Blue black 694 nm QS-ruby
  - ▶ Green 755 nm QS-alexandrite

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- ▶ ▶ Red 585 nm PDL, 532 nm FD-Nd:YAG



# Tattoo removal with Q-switched Ruby laser



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## ➤ Photorejuvenation

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# Treatment of aging skin

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The skin's natural aging process manifests as contour changes and rhytids secondary to the depletion of subcutaneous fat & the loss of dermal collagen.

- ▶ environmental factors
- ▶ UV light: photoaging

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▶ A 69-year-old man who drove a delivery truck for 28 years shows damaged skin on the left side of his face.

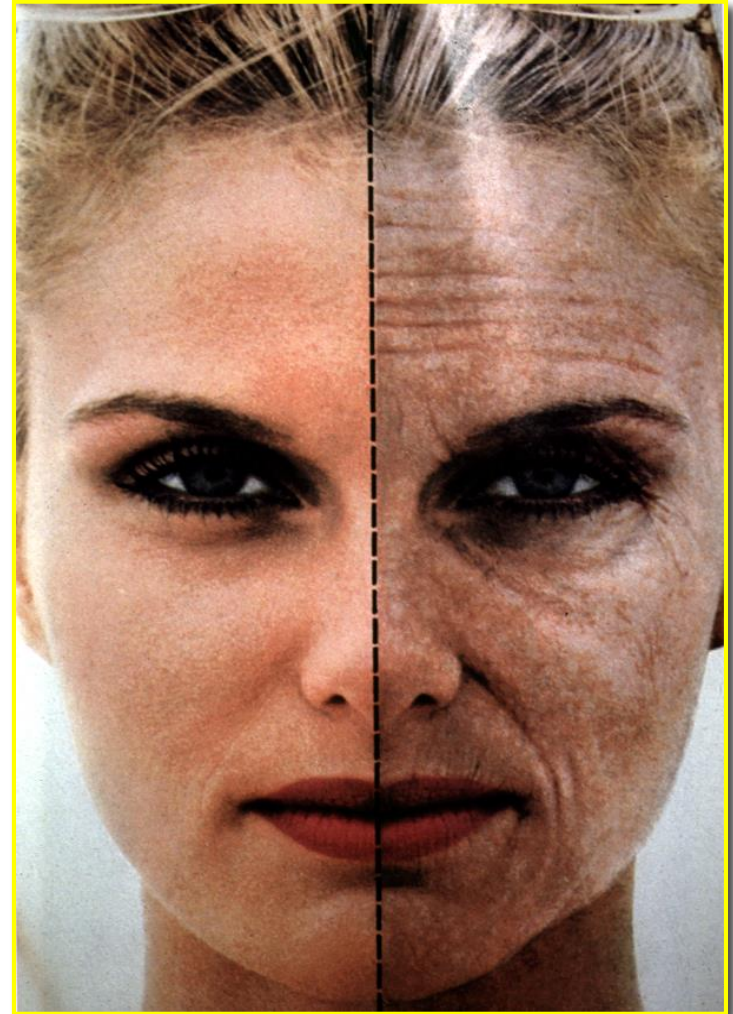
NEW ENGLAND JOURNAL OF MEDICINE



# Signs of aging skin

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- ▶ wrinkles, lines
- ▶ age spots
- ▶ uneven skin texture
- ▶ uneven skin tone
- ▶ roughness













# Resurfacing, Photorejuvenation

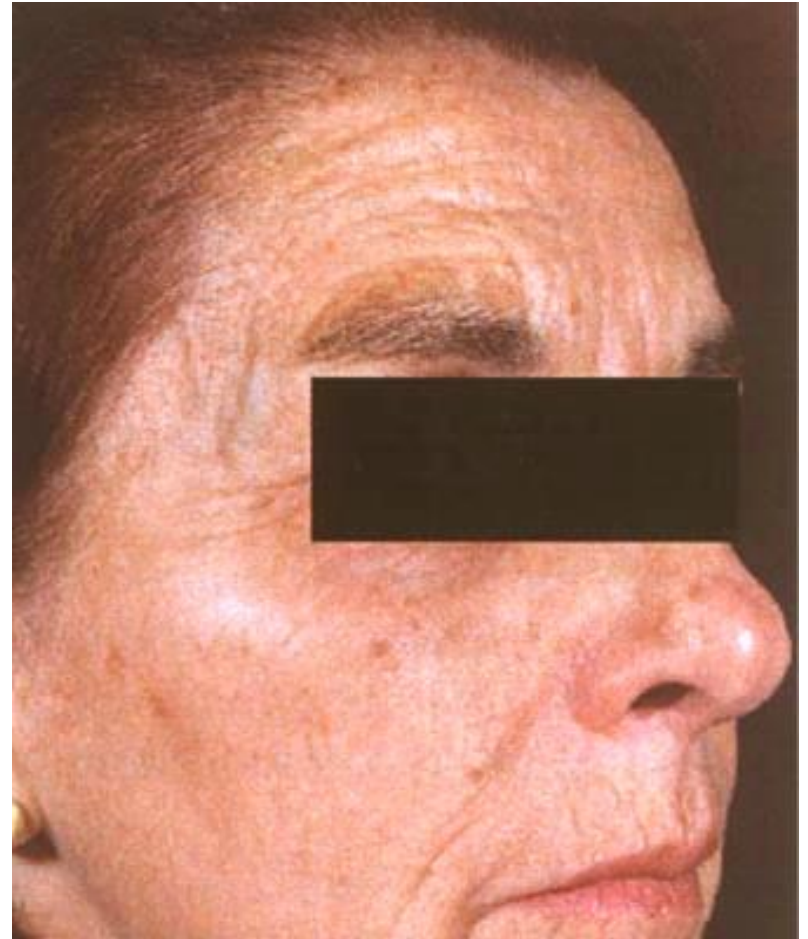
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- ▶ Non-ablative photorejuvenation:
  - ▶ IPL
  - ▶ Nd:YAG
  - ▶ Diode laser 1450 nm
  - ▶ Er:glass 1540 nm
- ▶ Ablative laser resurfacing
  - ▶ 2940 nm Er:YAG
  - ▶ fractional Er:YAG
  - ▶ fractional 10600 nm CO<sub>2</sub>



# Photorejuvenation with IPL

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# Ablative lasers

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- ▶ infrared spectrum (Er:YAG, CO<sub>2</sub>)
- ▶ chromophore: water
- ▶ effect independent of other chromophores



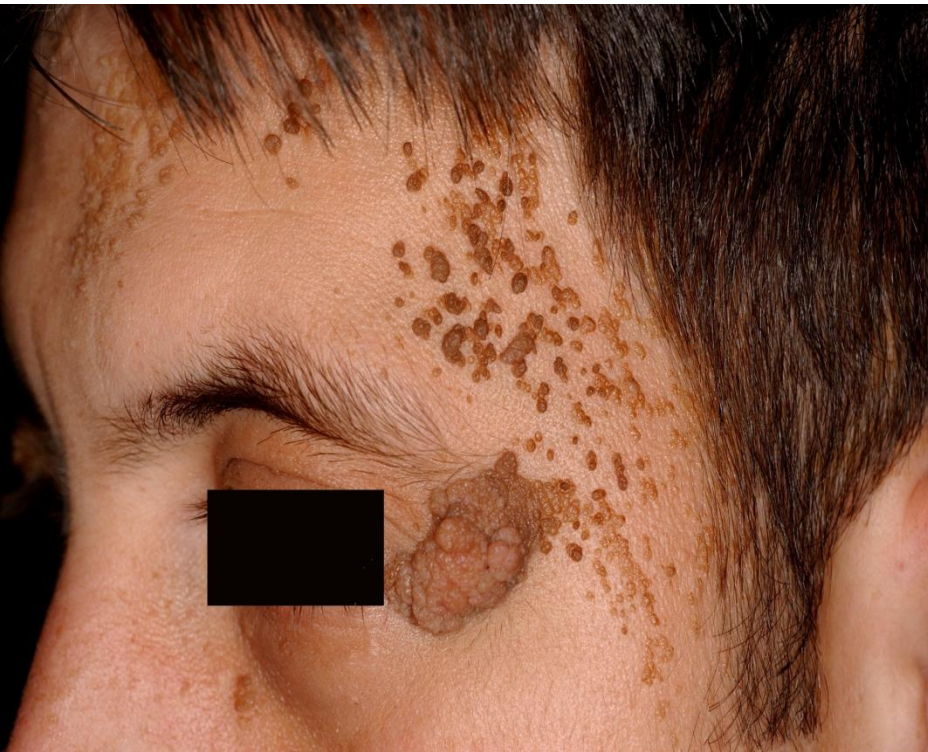
# Ablative laser treatment of an epidermal verrucous naevus with CO<sub>2</sub> laser



# CO<sub>2</sub> laser treatment of epidermal verrucous naevus

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before



after



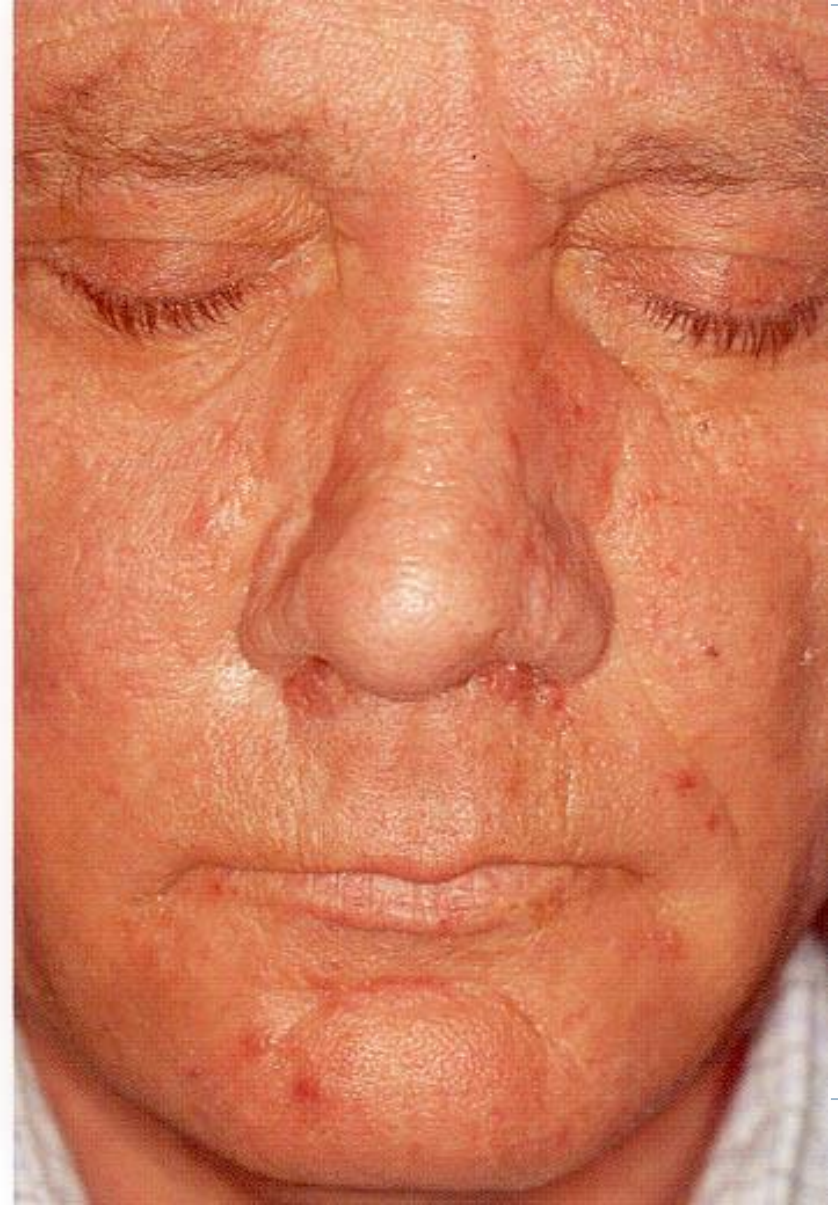


Soot particles: CO<sub>2</sub> laser 1x





# Ablative laser treatment of rhynophyma with CO<sub>2</sub> laser



# CO<sub>2</sub> laser treatment of xanthelasmas

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# CO<sub>2</sub> laser vaporization of verrucae planae

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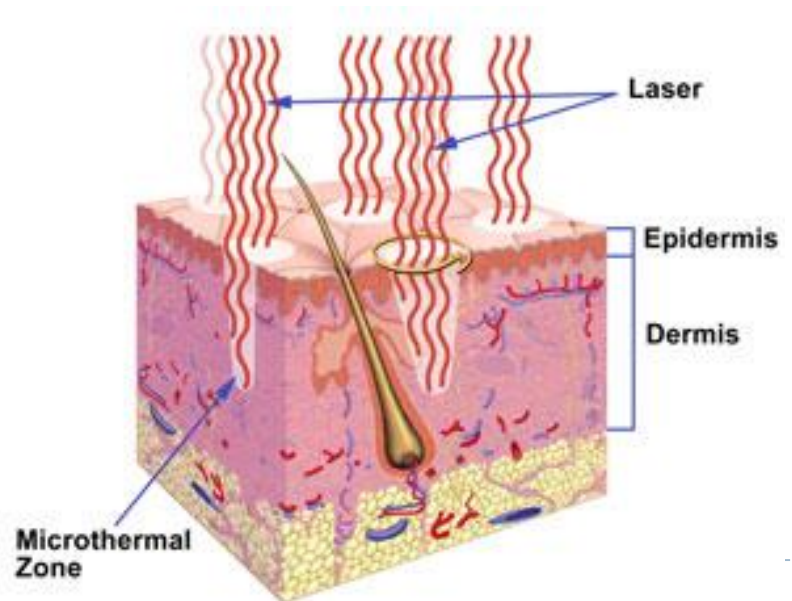
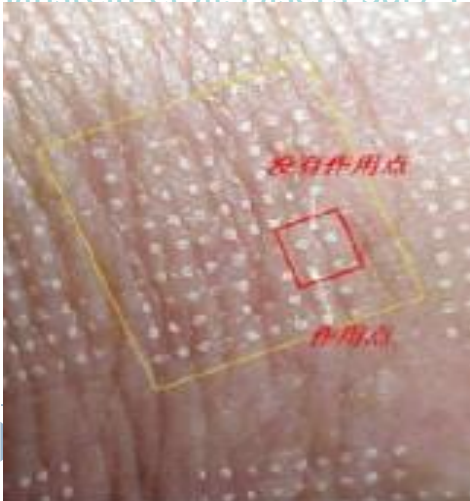


# Fractional photothermolysis

- Fractional lasers

- 1550 nm Er fiber laser, 2940 nm Er:YAG, 10600 nm CO<sub>2</sub>
- target: water
- tissue damage and remodelling in microscopic thermal zones (MTZ)
- surrounding tissues are spared
- pigmented lesions, rejuvenation

Manstein et al Lasers Surg Med 2004



# Skin reaction immediately after fractional CO2 treatment

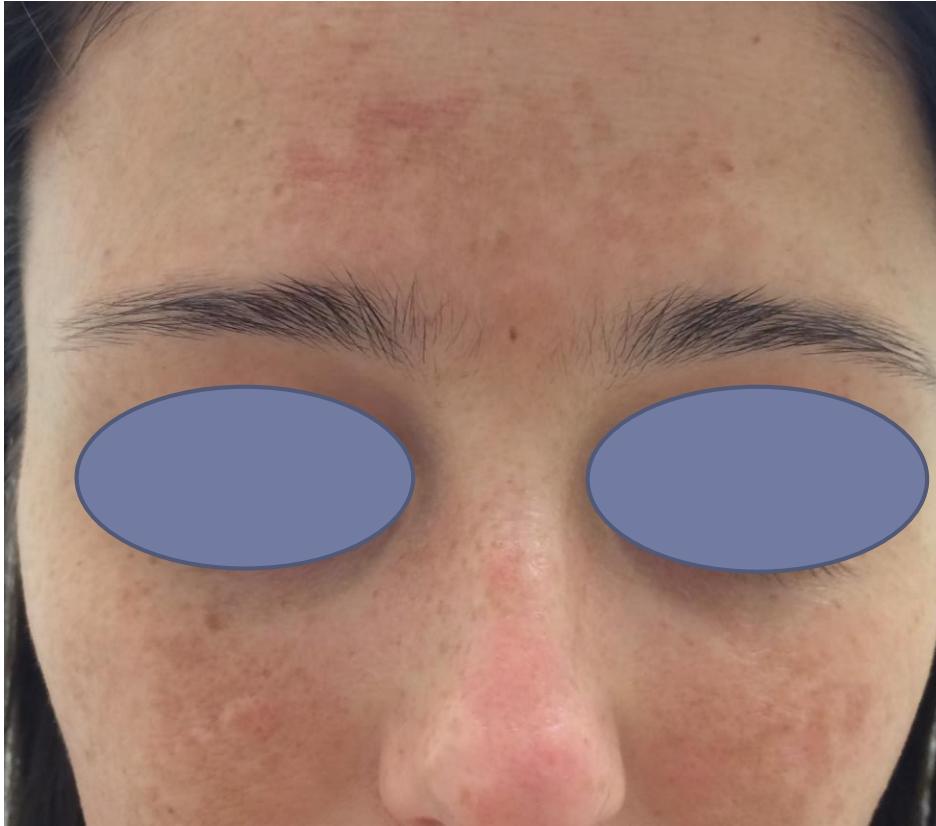


# Melasma fractional CO2 treatment (1 session)



# Melasma fractional CO2 treatment (1 session)

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# Melasma fractional CO2 treatment (1 session)

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# Combined non-ablative and ablative fractional rejuvenation

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- ▶ Fotona 4 D resurfacing
- ▶ Step 1: intraoral tightening Er:YAG “smooth” mode (non-ablative)
- ▶ Step 2: Nd:YAG “Frac 3” mode (short pulse,  $\mu\text{s}$ )
- ▶ Step 3: Nd:YAG “piano” mode: heating (long pulse, seconds)
- ▶ Step 4: Er:YAG peeling



# Other applications of lasers in dermatology

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- ▶ XeCl excimer laser (308 nm: UVB)
  - ▶ psoriasis
  - ▶ vitiligo
- ▶ multiplex laser in nail psoriasis
- ▶ onychomycosis laser treatment



# Treatment of psoriasis with excimer laser (308 nm)



# Treatment of vitiligo with excimer laser (308 nm)



# Efficacy of Multiplex laser (PDL+Nd:YAG) in nail psoriasis

before treatment

after 5 treatments



Multiplex: 7 mm spot size, PDL/Nd:YAG 7/40 J/cm<sup>2</sup>, pulse duration 10/15 ms



# Laser therapy of onychomycosis

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- ▶ near infrared spectrum
  - ▶ deep penetration
  - ▶ heating of nail bed ~ 50° C
- ▶ Nd:YAG laser
- ▶ Titanium sapphire (800 nm, femtosec) (in vitro) *Manevitch, et al, Photochem Photobiol*
- ▶ non-thermal lasers
  - ▶ diode laser 870 nm and 930 nm, 1.7 W/cm<sup>2</sup> for several minutes,
  - ▶ „photo-inactivation”, 30 % mycologic cure rate, 3-4 mm longitudinal nail growth after 6 months
  - ▶ diode 635 nm and 405 nm (no mycologic evaluation)

*Landsman et al, J Am Podiatr Med Assoc*

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# Laser therapy of onychomycosis: 1064 nm Nd:YAG

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## Clinical trials:

- methodology was not comprehensive
- reporting of outcomes was not unified
- small, uncontrolled and non-randomized trials
- meta-analysis is not possible
  - lack of mycological evaluation or only microscopic examination
  - the number of treatments, time intervals between them and follow-up periods varied



# Laser therapy of onychomycosis: What treatment parameters we have to choose?

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- ▶ **Optimization of parameters** (Gupta, J Dermatolog Treat, 2016)
  - ▶ The nail plate has to reach a relatively high temperature, while the nail bed temperature has to remain under 45° C (pain, dermal necrosis).
- ▶ Wavelength?
  - ▶ penetration into the nail plate (750-1300 nm)
  - ▶ absorption in the target (less in surrounding tissue)
  - ▶ selective photothermolysis of the fungal elements
  - ▶ *T. rubrum* absorption peak 415 nm, under research





# Complications of laser treatment

\*Generally it is very safe with very low incidence of side effects

- scarring(<1%)
- hyperpigmentation ( 10 - 15% , transient, resolves in 2-3 months)
- hypopigmentation (5%, transient, resolves within 2 months)
- demarcation lines
- delayed wound healing
- persistent erythema
- infections
- purpura



# Complications of laser treatment: purpura

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- ▶ Purpura and odema occurring after the treatment were transient.



„Although facial teleangiectasia do improve after a single purpura-free treatment with PDL, they improve more after purpura is induced.”

Murad Alam, Jeffrey Dover, Kenneth Arndt;

- ▶ Derm Surg, July 2003

# Postinflammatory hyperpigmentation

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# Pretreatment measures

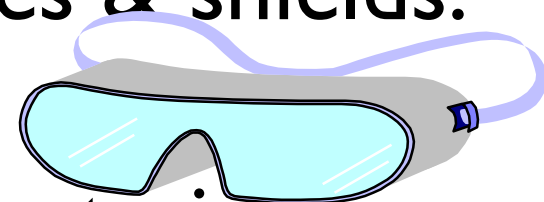
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- ▶ written consent
- ▶ pretreatment photograph
- ▶ anesthesia (usually topical)
- ▶ safety measures (precautions)



# Safety measures (precautions)

-Protect eyes → eye glasses & shields.



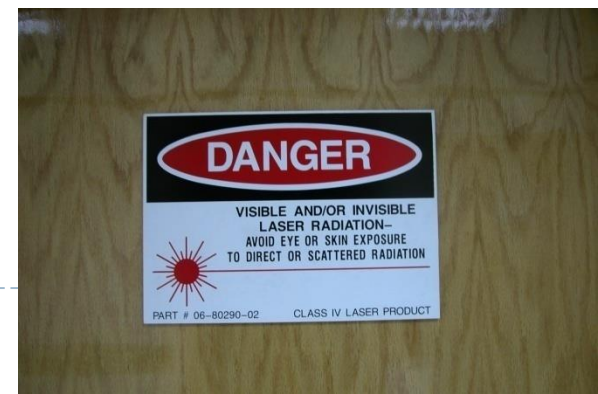
-Laser off or standby when not in use.

- steam → smoke evacuator

- CO<sub>2</sub> laser → no alcohol containing wipes

-Avoid reflecting objects

-Labeling the theatre



# Post treatment measures

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- ▶ sunscreen for 3 months after the end of last session.
- ▶ topical antibiotic ointment twice/day until disappearance of purpura / crust.
- ▶ bleaching agent whenever there is history of PIH.



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