

Aparatura Medyczna

#6

dr inż. Dawid Kucharski

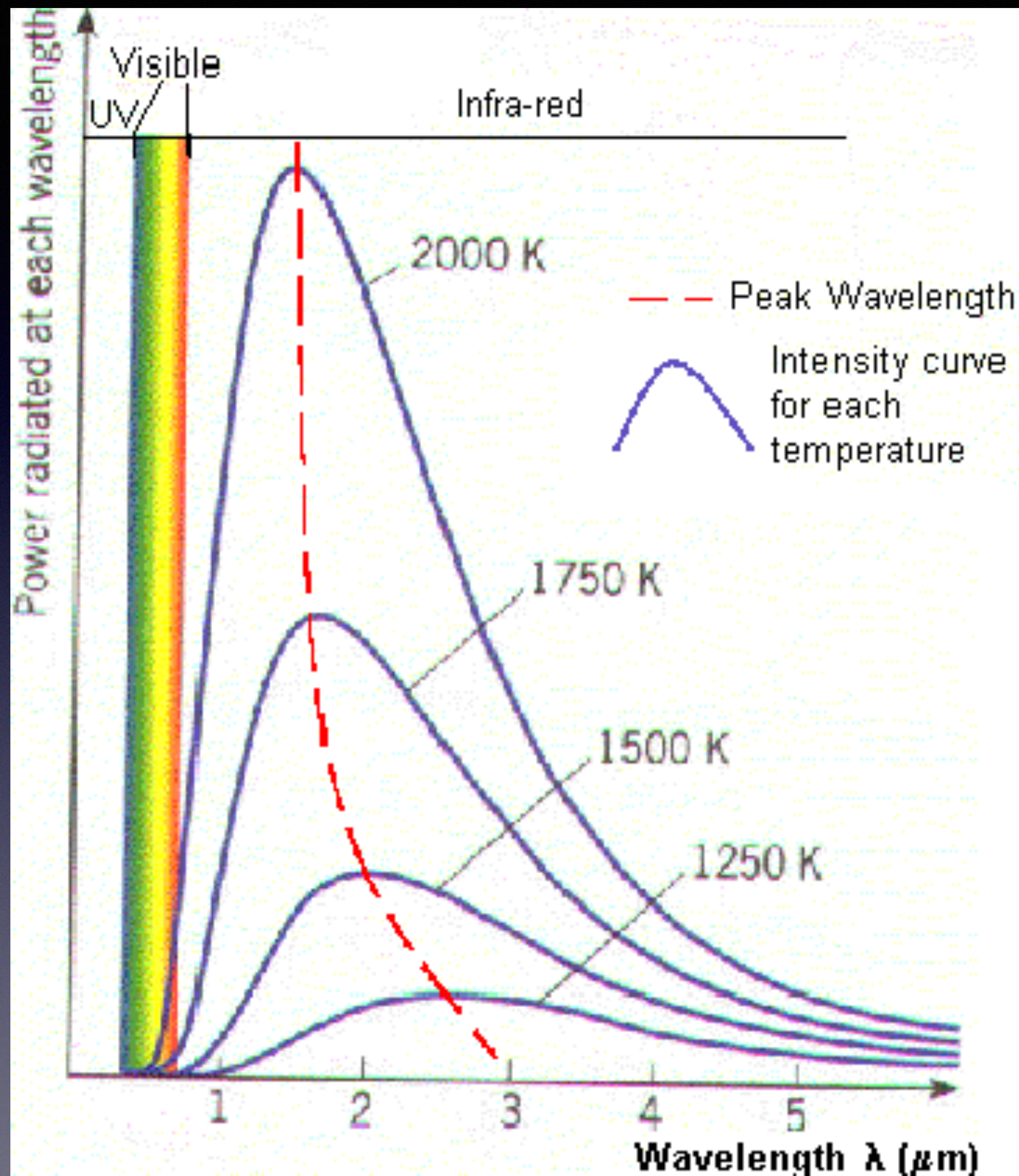
Zakład Metrologii i Systemów Pomiarowych
Instytut Technologii Mechanicznej
Wydział Budowy Maszyn i Zarządzania
Politechnika Poznańska

pokój 129 CM (lab. 135, 214, 212 CM)

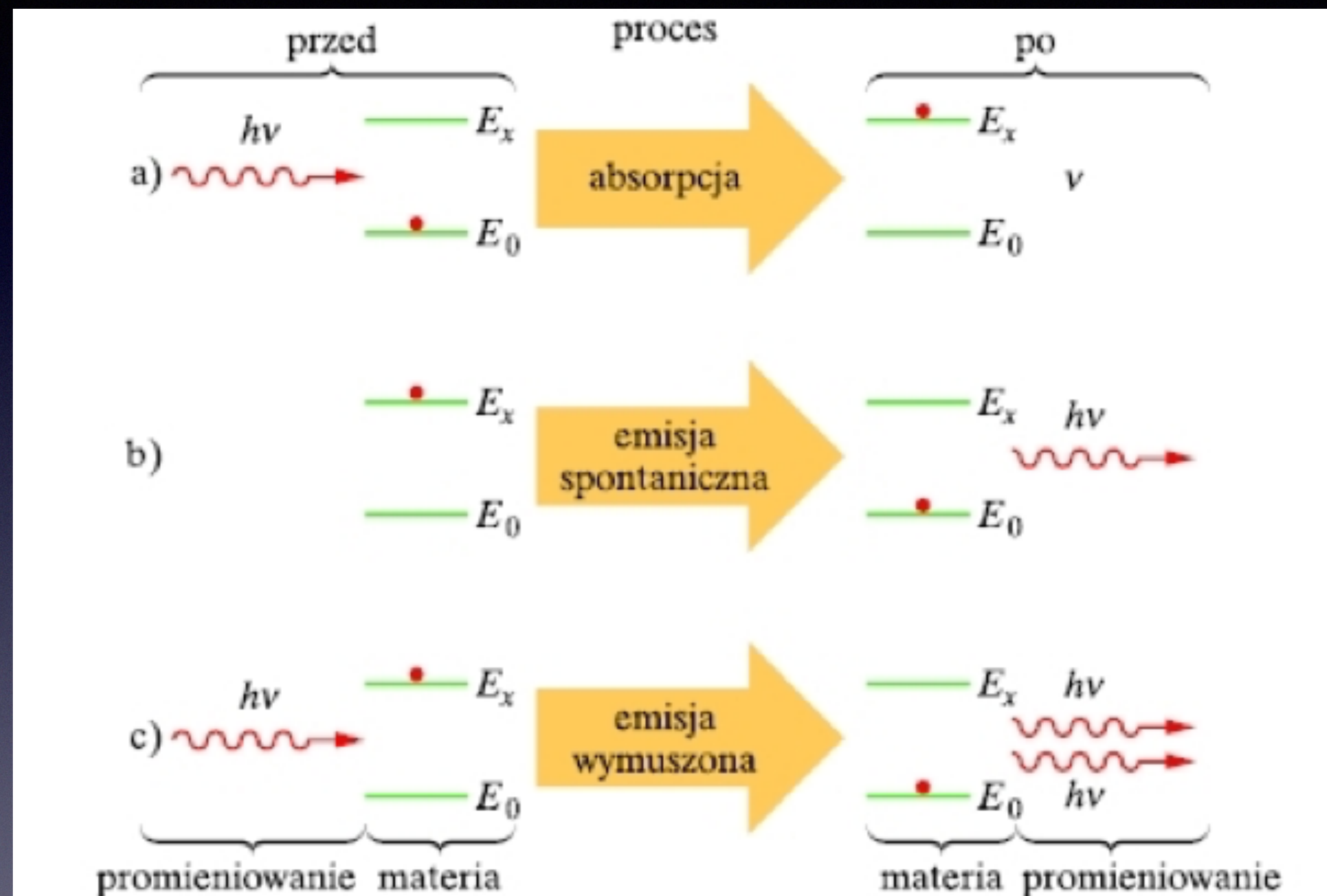
dawid.kucharski@put.poznan.pl

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W klasycznych źródłach dominują efekty cieplne



Specyficzne właściwości światła laserowego

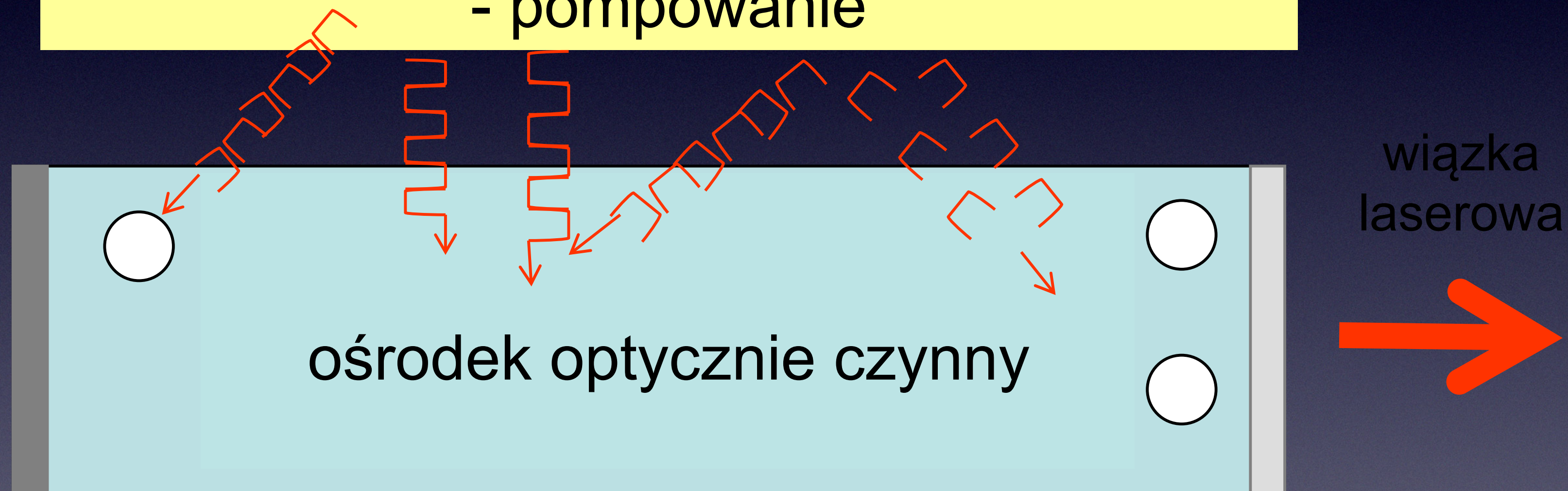
- a) bardzo wysoki stopień monochromatyczności;
- b) bardzo wysoki stopień spójności (koherencji - zdolność dwóch wiązek do interferencji). Długość spójności dla laserów sięga nawet do setek kilometrów (dla żarówki droga spójności jest zwykle mniejsza niż metr);
- c) wysoki stopień ukierunkowania
- d) wiązkę można dużo dokładniej skupiać - ogniskować, przez co można uzyskać gęstość mocy rzędu 10^{17} W/cm^2 (palnik tlenowo-acetylenowy - 10^3 W/cm^2);
- e) możliwość wytwarzania bardzo krótkich impulsów:
$$P = E/t, P \approx 10^{14} \text{ W}$$



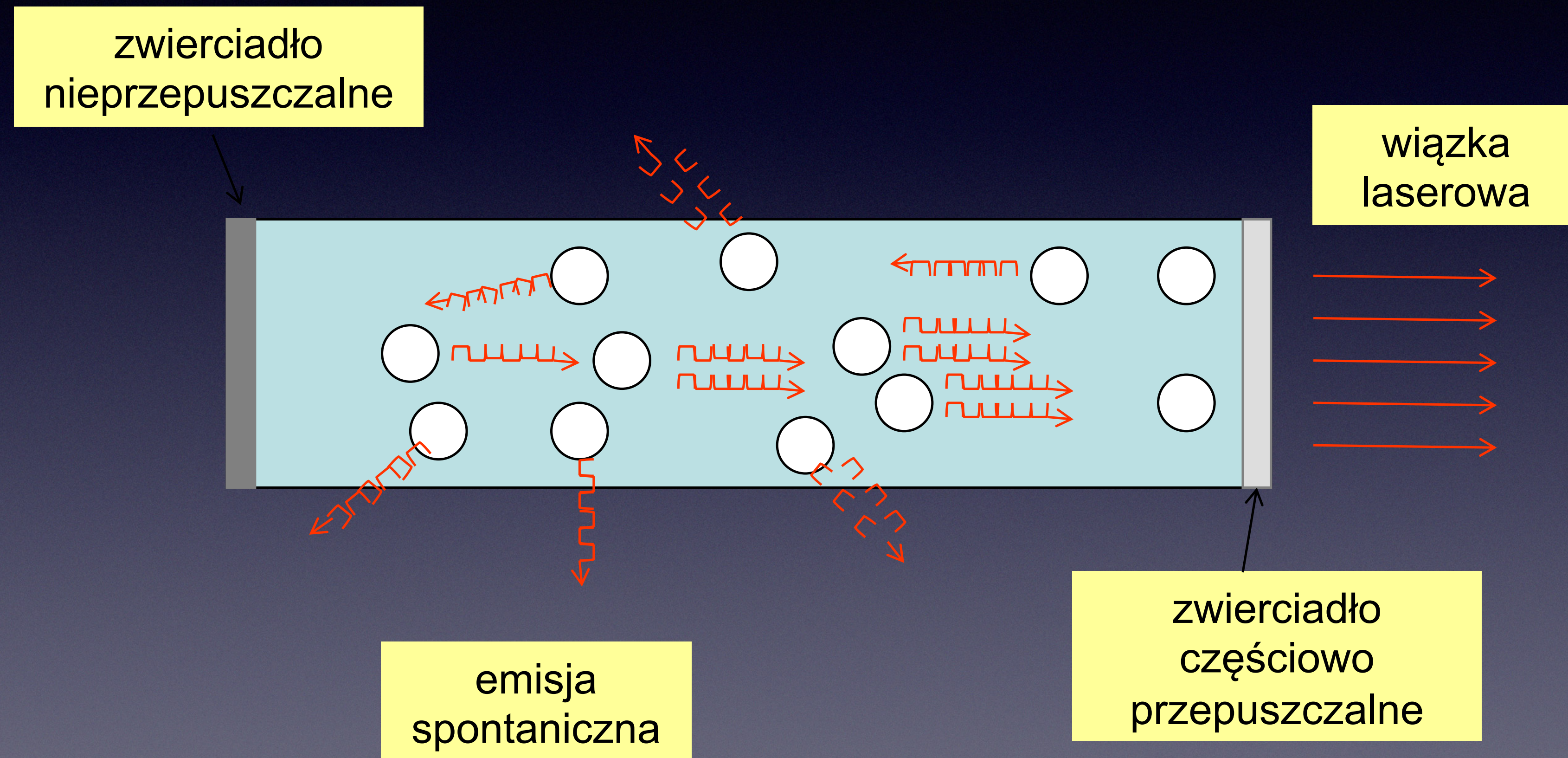
<https://qph.fs.quoracdn.net/main-qimg-b6dbf183e4c4fb15bffa71e652faa85-c>

Laser

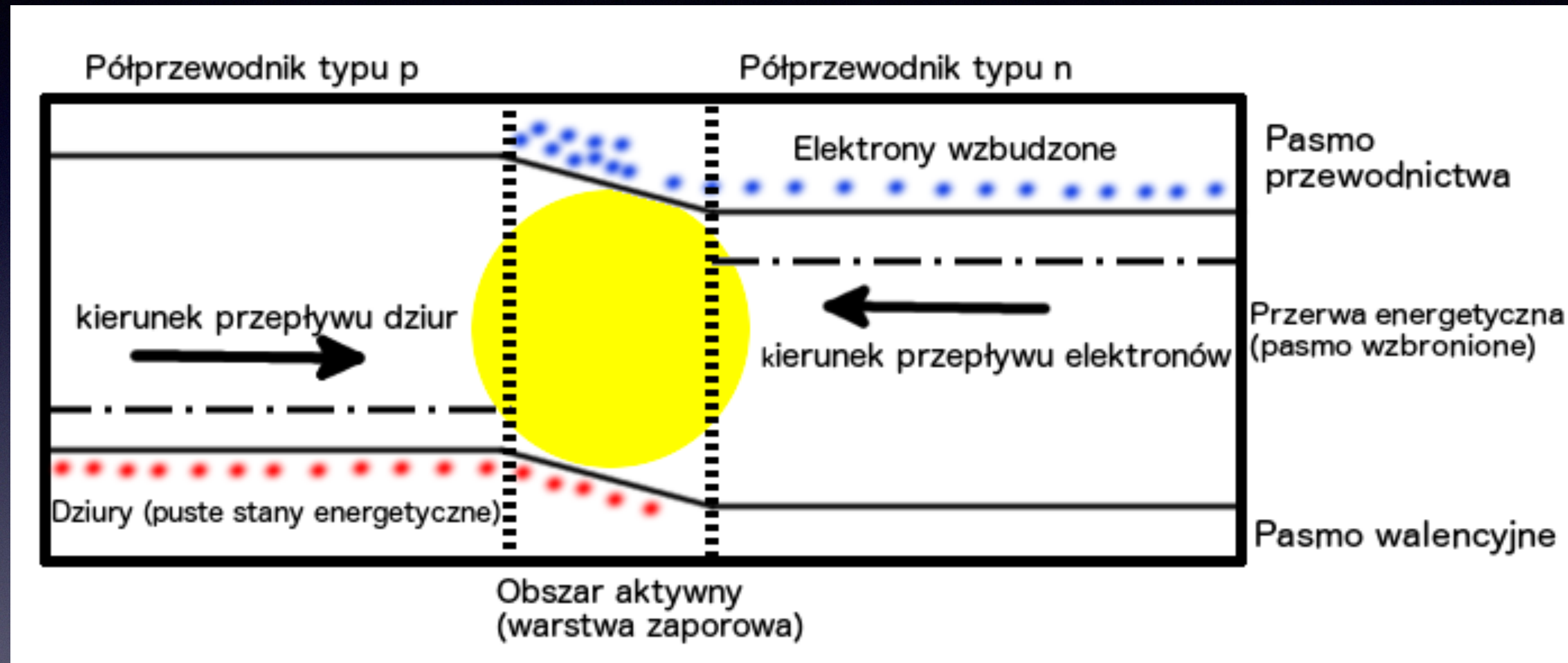
wzbudzenie ośrodka optycznie czynnego
- pompowanie



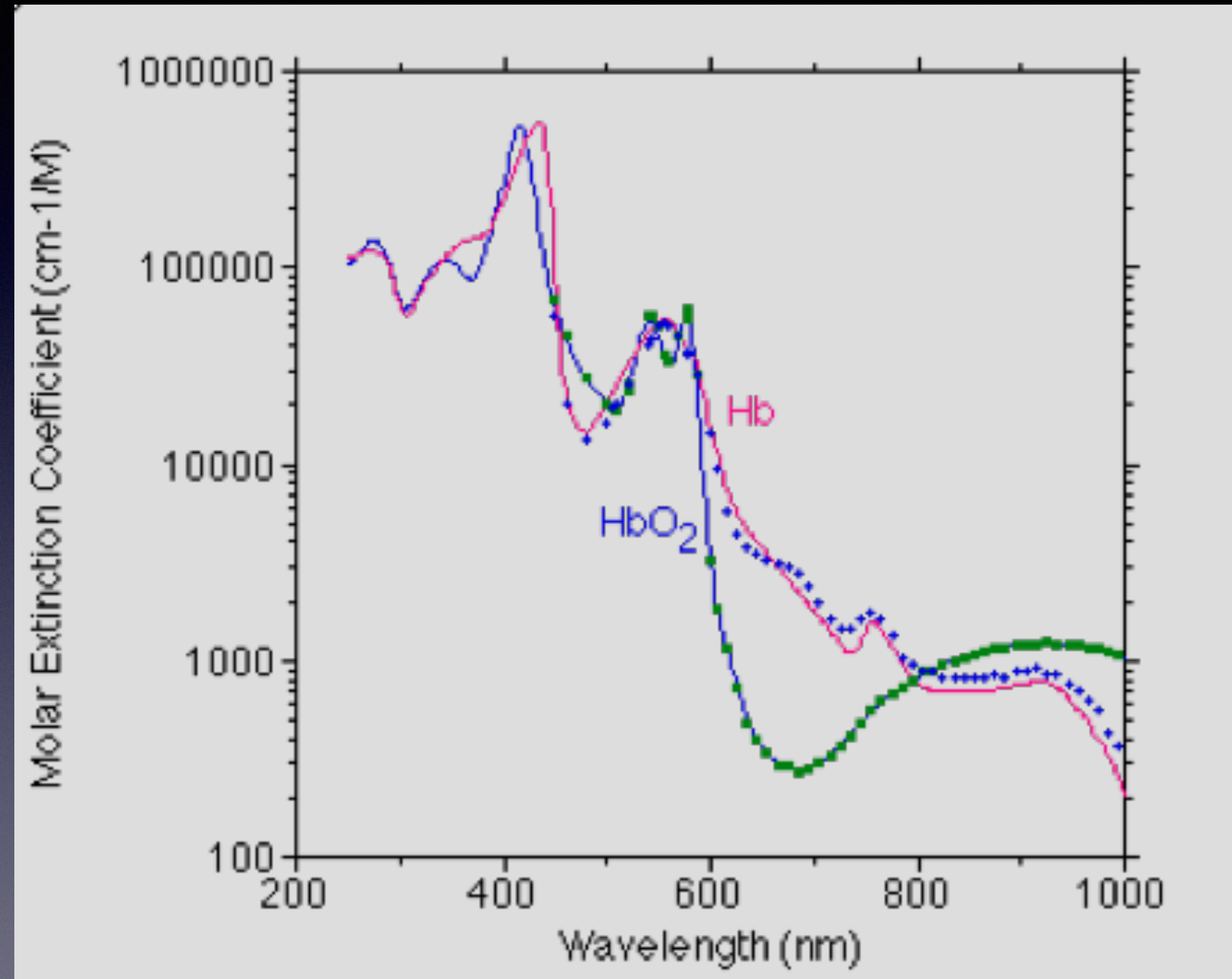
Rezonator laserowy



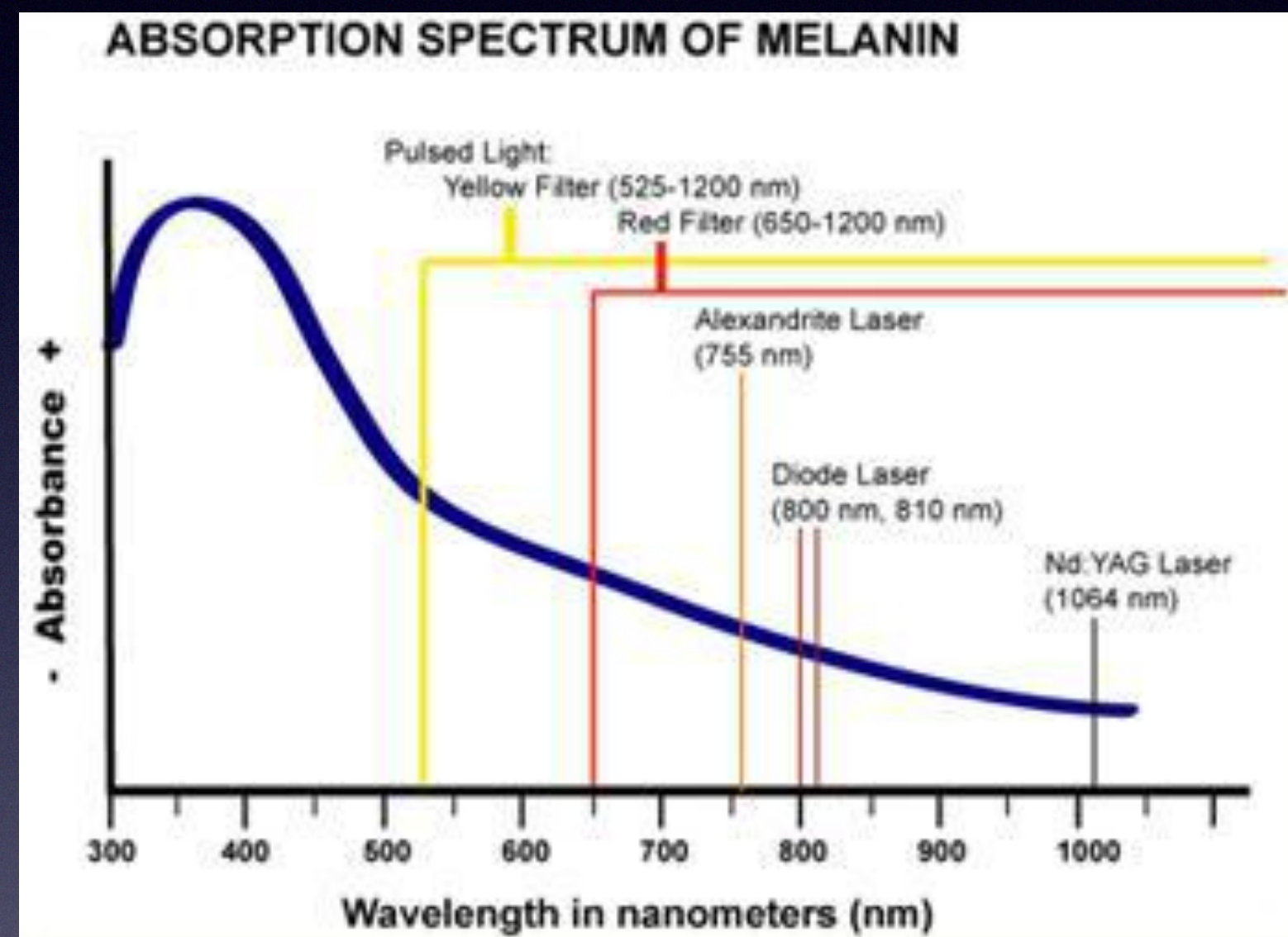
Laser półprzewodnikowy



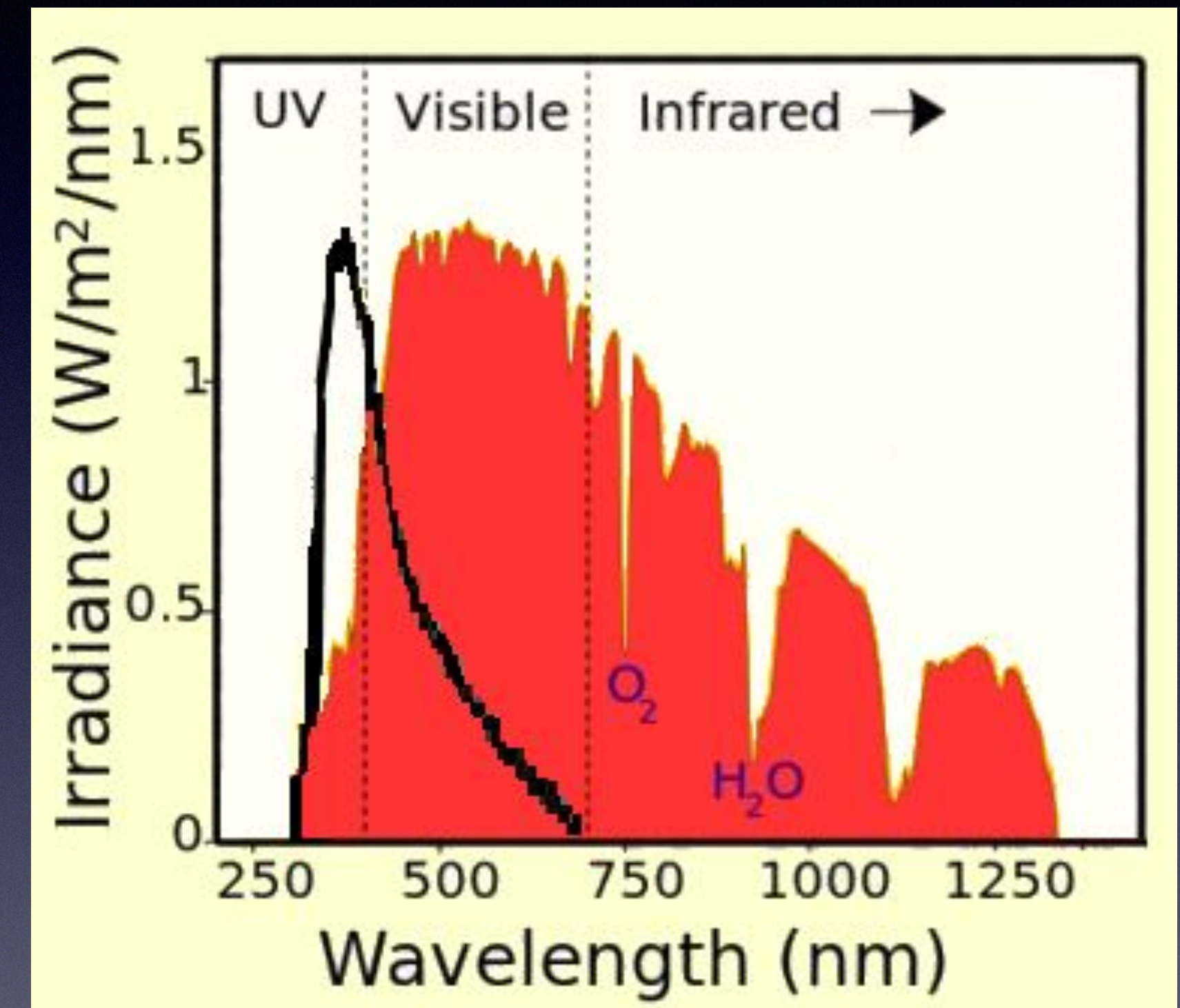
Widmo absorpcji hemoglobiny



Widmo absorpcji melaniny

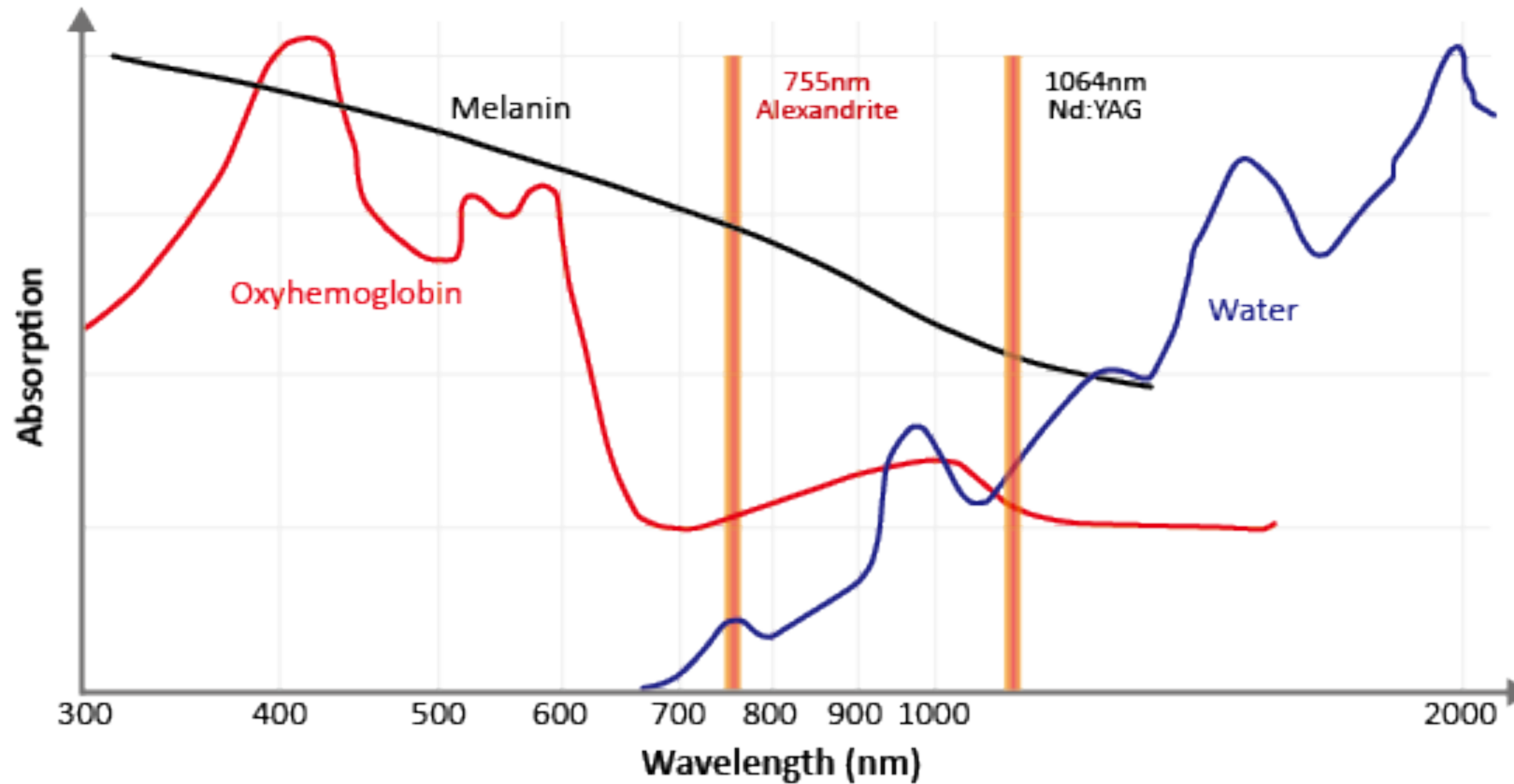


<https://www.lumiermedical.com/contents/additional-services/permanent-hair-reduction>

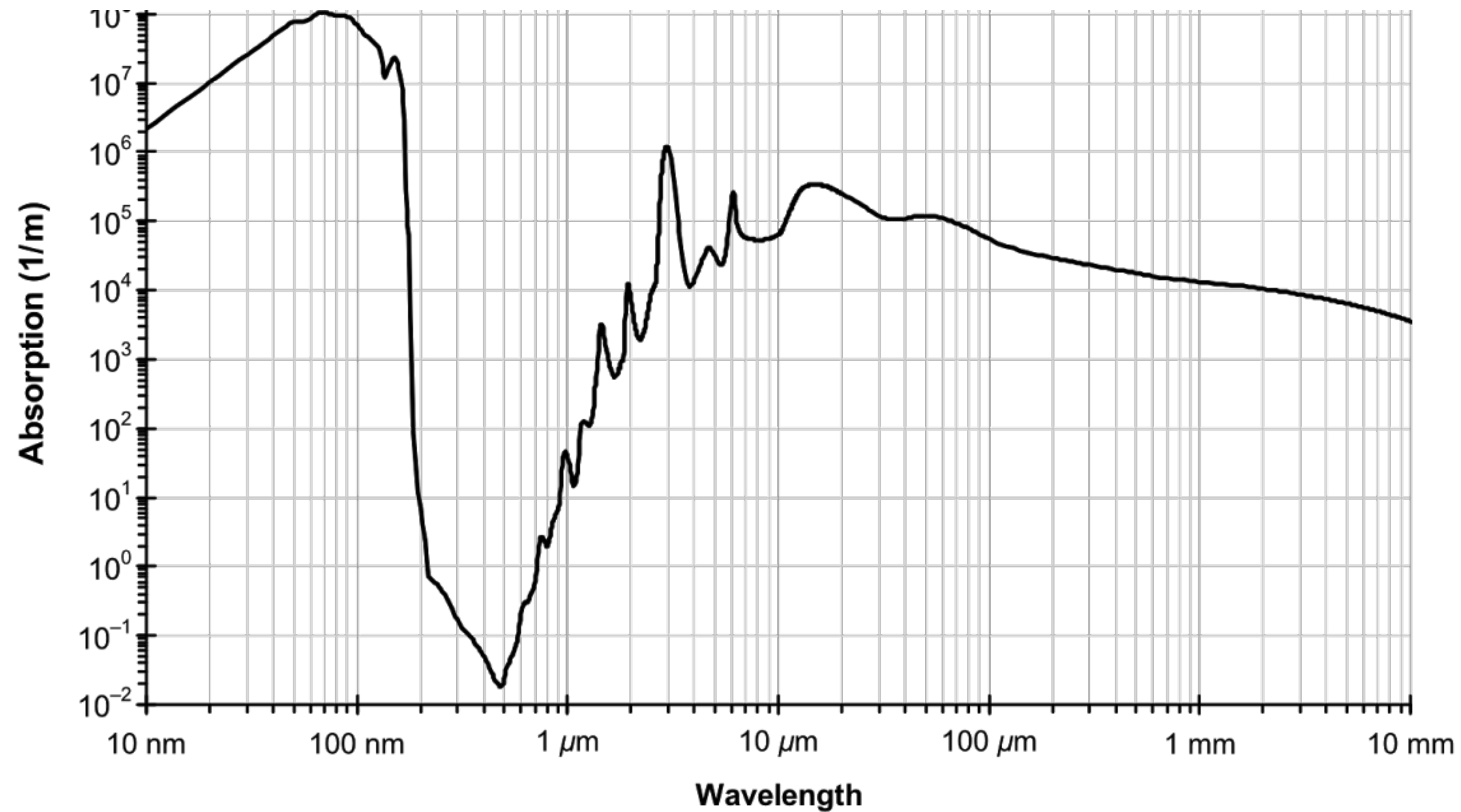


<http://www.chm.bris.ac.uk/motm/melanin/melaninh.htm>

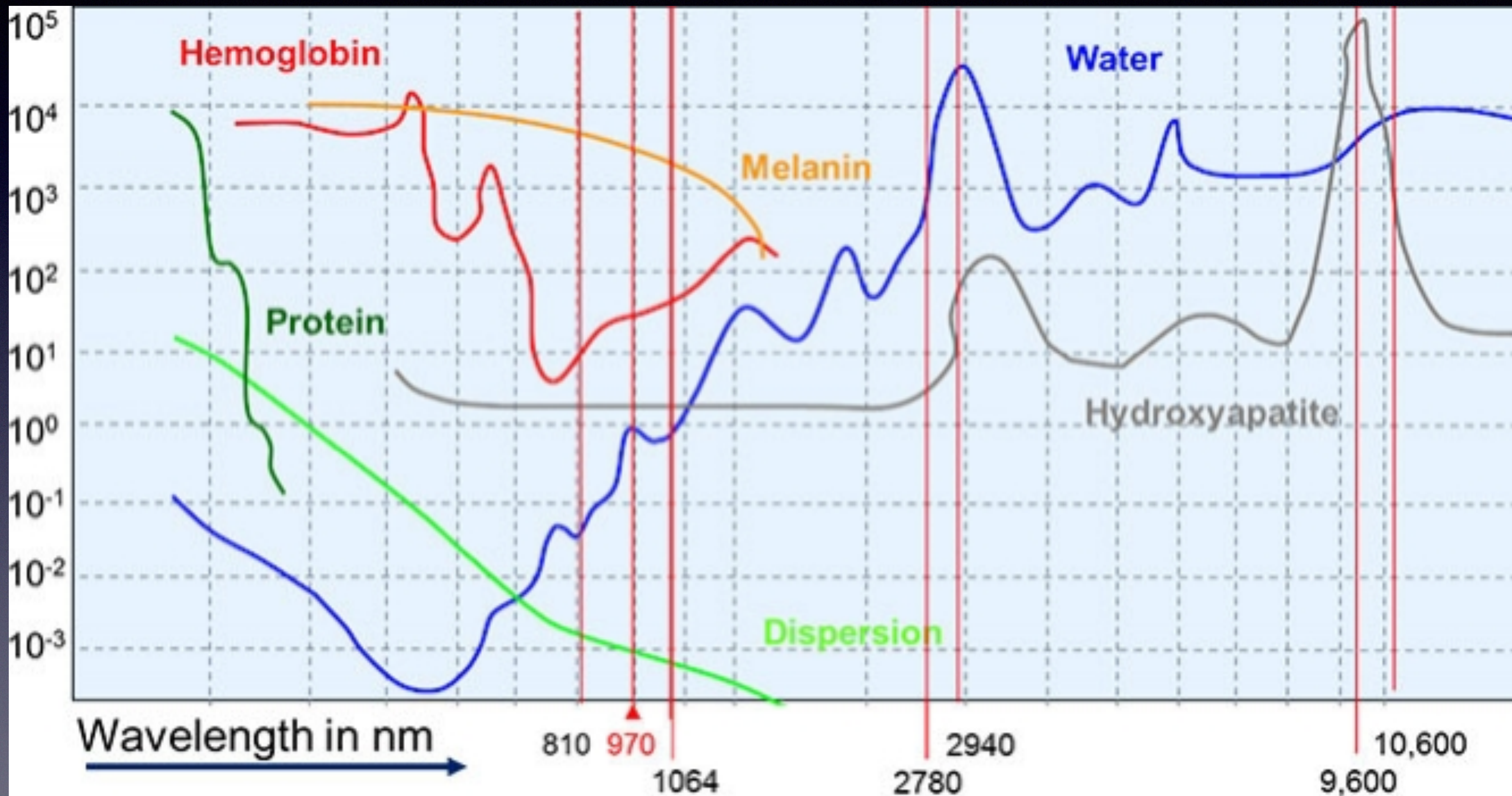
Widmo absorpcji chromoforów



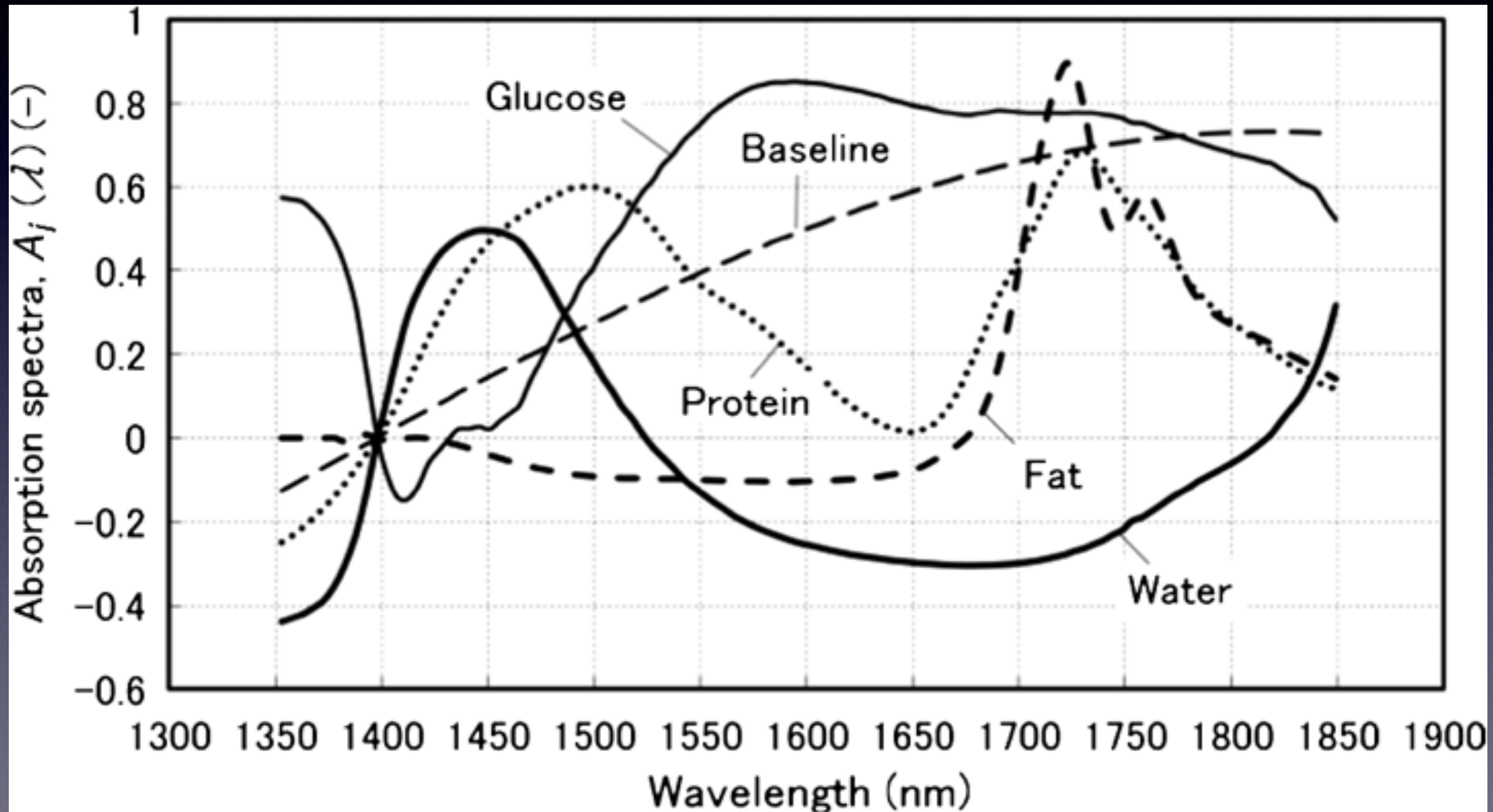
Widmo absorpcji wody



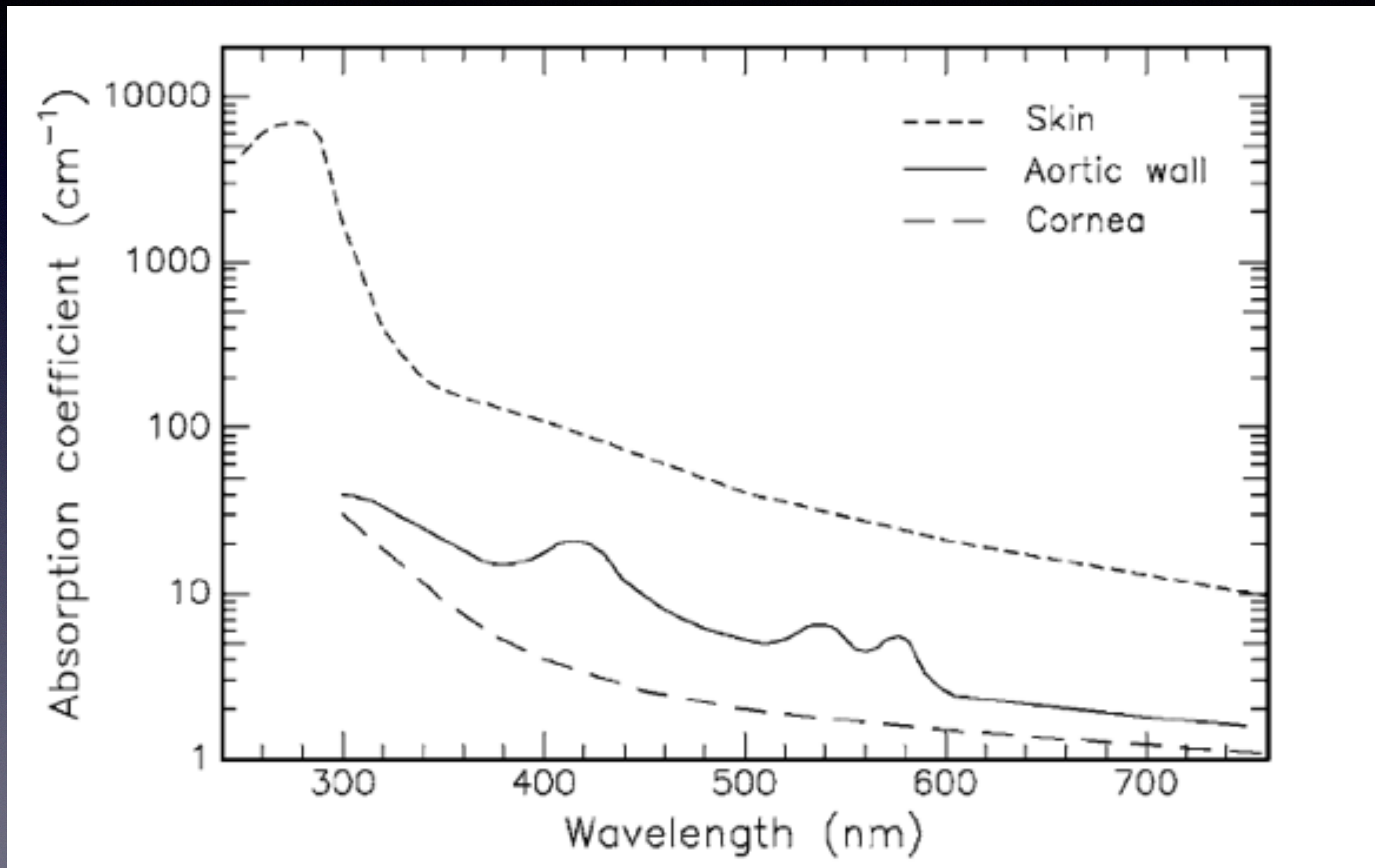
Widmo absorpcji chromoforów



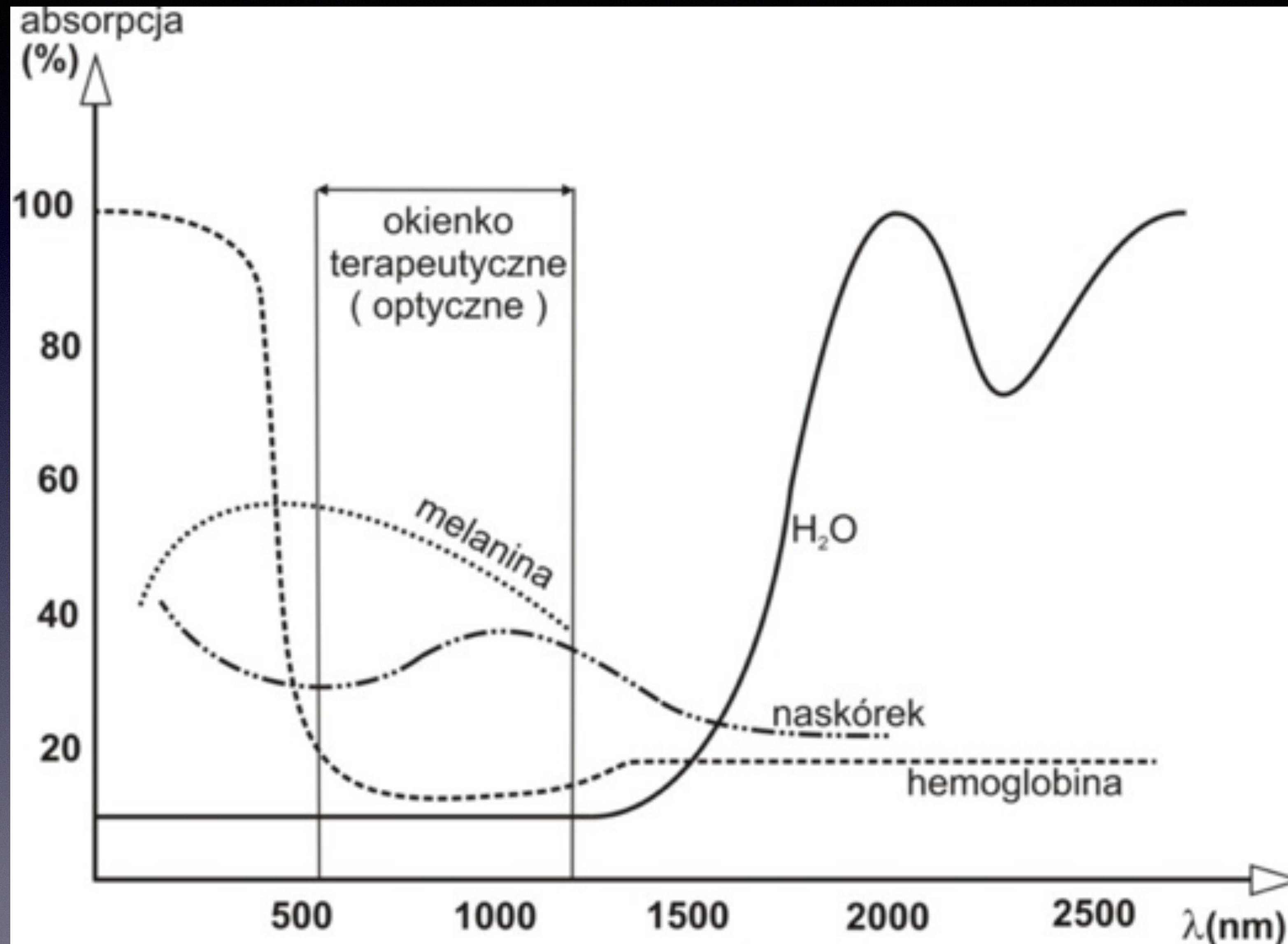
Widmo absorpcji



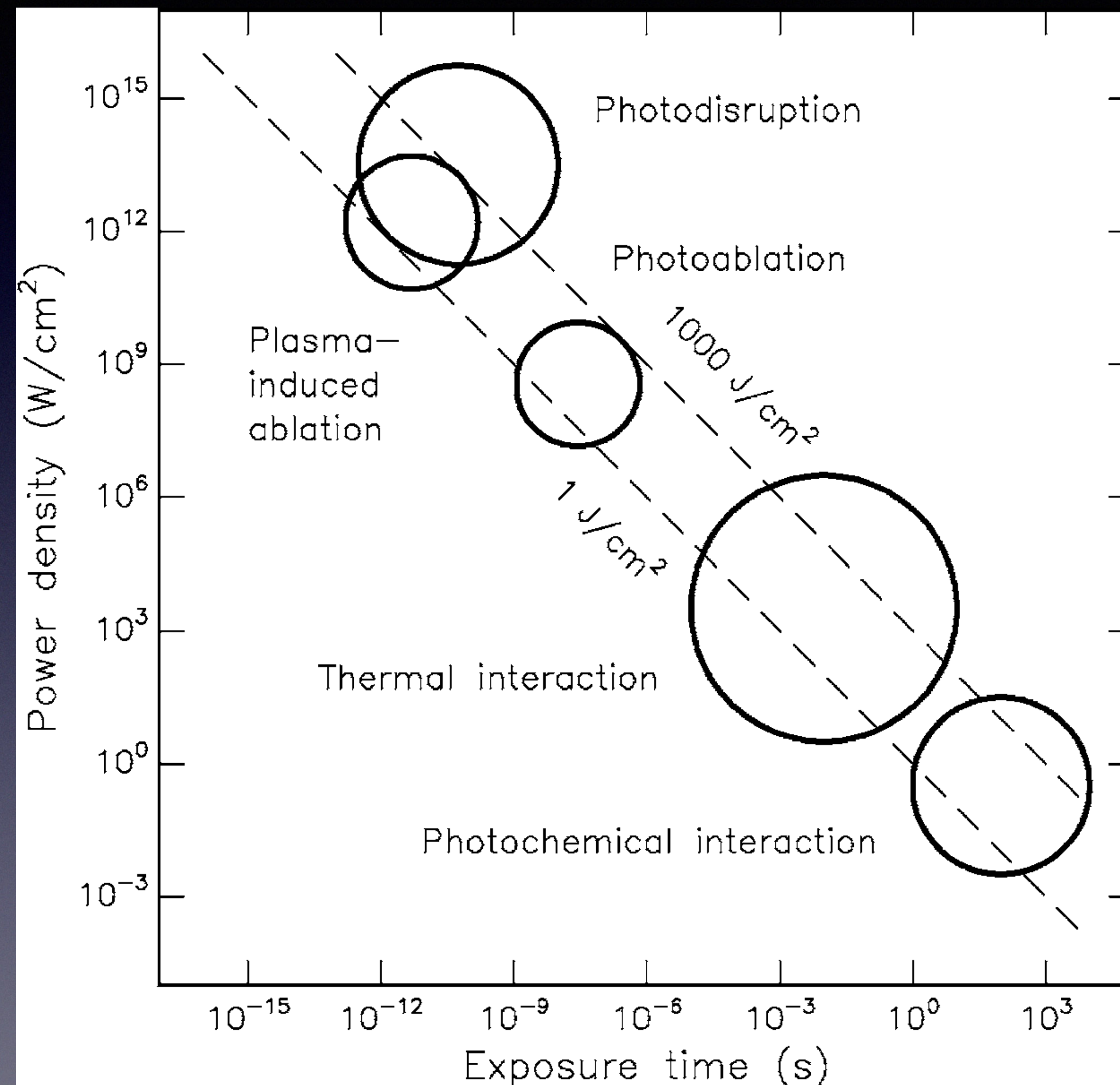
Widmo absorpciji



Oddziaływanie laserowe



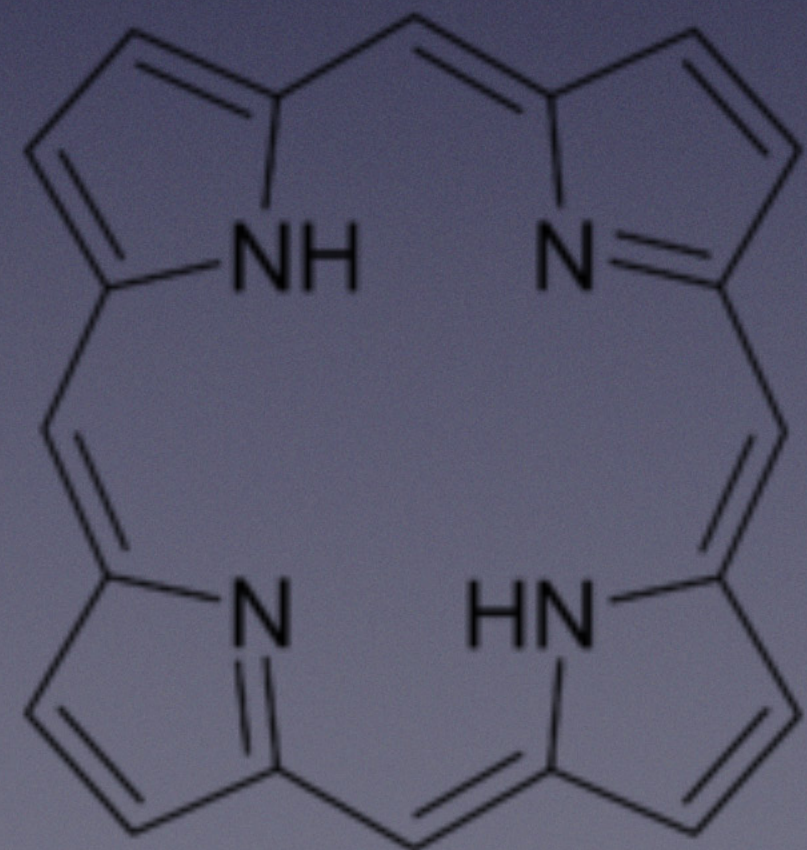
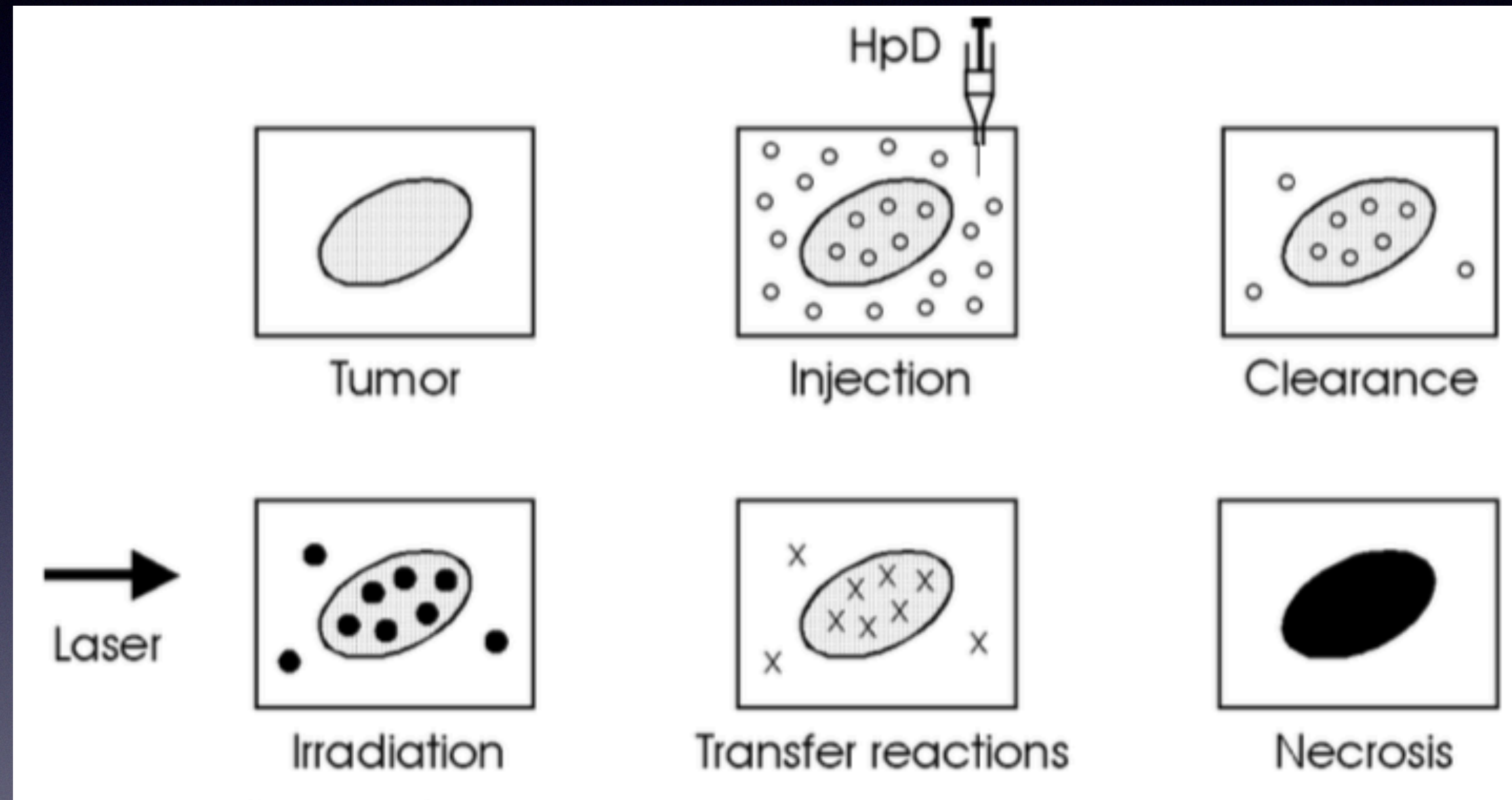
Oddziaływanie laserowe



Oddziaływanie laserowe - chemiczne

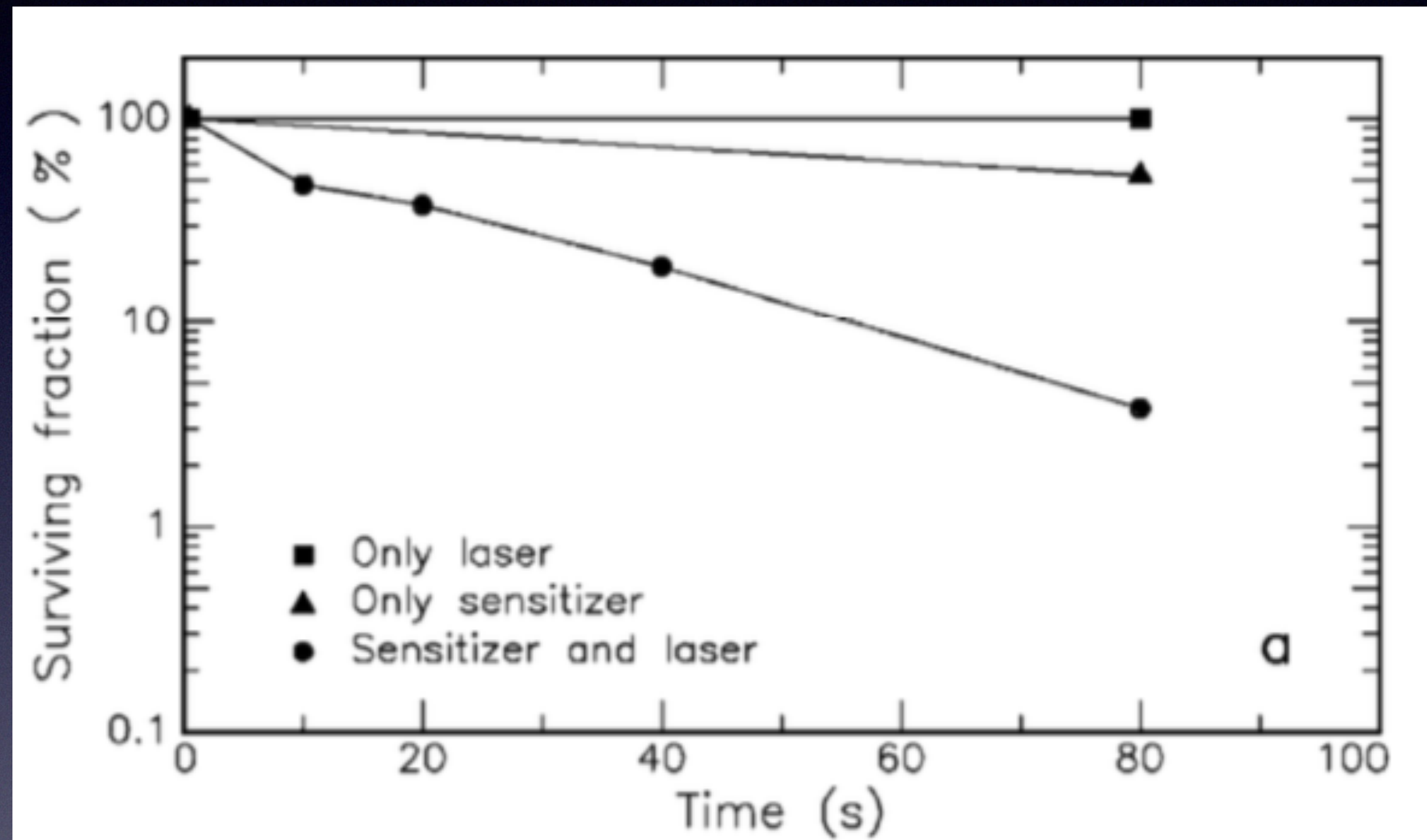
<i>Excitation</i>	
• Singlet state absorption	${}^1S + h\nu \implies {}^1S^*$
<i>Decays</i>	
• Radiative singlet decay	${}^1S^* \implies {}^1S + h\nu' \text{ (fluorescence)}$
• Nonradiative singlet decay	${}^1S^* \implies {}^1S$
• Intersystem crossing	${}^1S^* \implies {}^3S^*$
• Radiative triplet decay	${}^3S^* \implies {}^1S + h\nu'' \text{ (phosphorescence)}$
• Nonradiative triplet decay	${}^3S^* \implies {}^1S$
<i>Type I reactions</i>	
• Hydrogen transfer	${}^3S^* + RH \implies SH^\bullet + R^\bullet$
• Electron transfer	${}^3S^* + RH \implies S^{\bullet-} + RH^{\bullet+}$
• Formation of hydrogen dioxide	$SH^\bullet + {}^3O_2 \implies {}^1S + HO_2^\bullet$
• Formation of superoxide anion	$S^{\bullet-} + {}^3O_2 \implies {}^1S + O_2^\bullet$
<i>Type II reactions</i>	
• Intramolecular exchange	${}^3S^* + {}^3O_2 \implies {}^1S + {}^1O_2^*$
• Cellular oxidation	${}^1O_2^* + \text{cell} \implies \text{cell}_{\text{ox}}$
<i>Carotenoid protection</i>	
• Singlet oxygen extinction	${}^1O_2^* + {}^1\text{CAR} \implies {}^3O_2 + {}^3\text{CAR}^*$
• Deactivation	${}^3\text{CAR}^* \implies {}^1\text{CAR} + \text{heat}$

Oddziaływanie laserowe - PDT

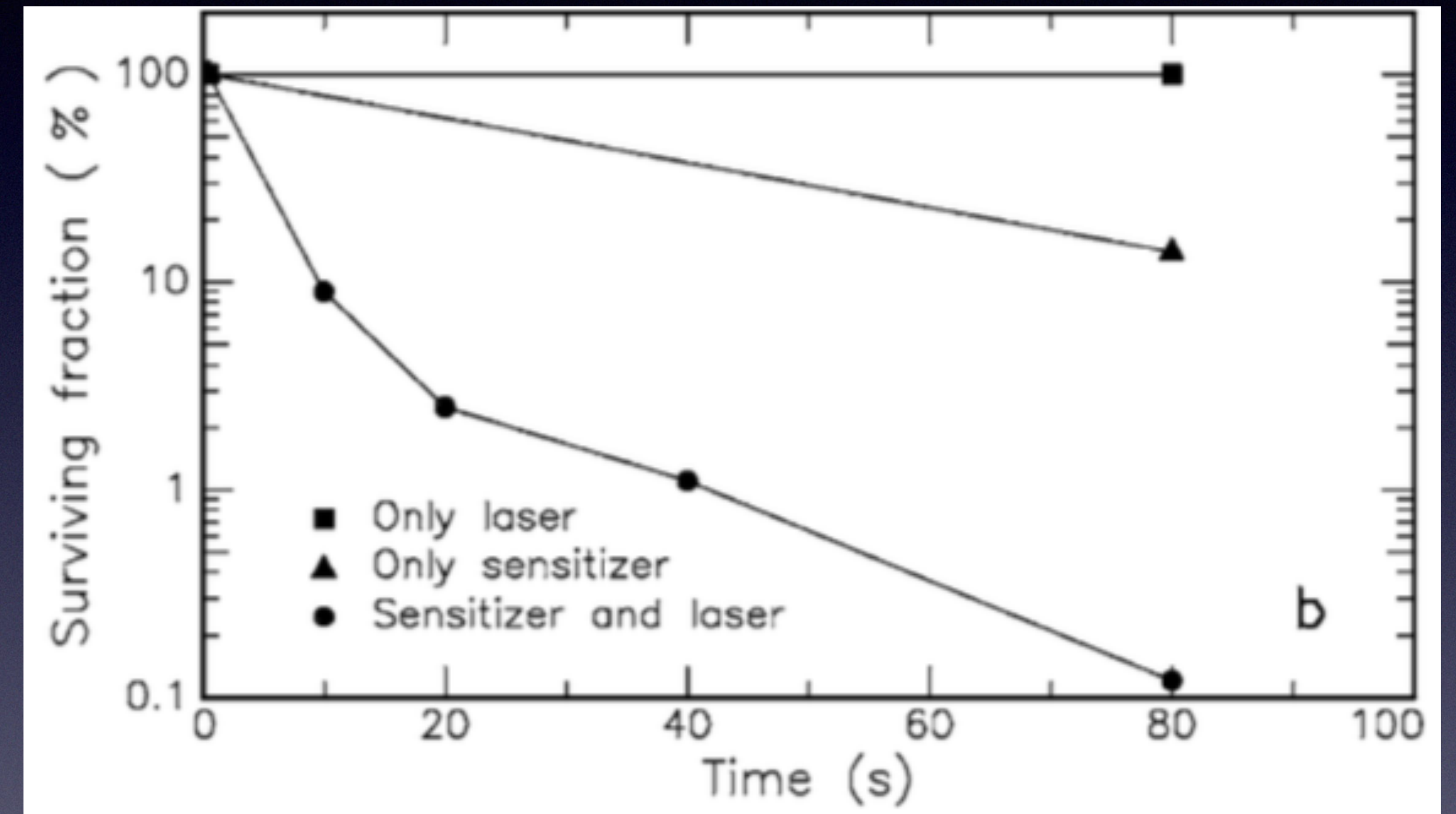


M. H. Niemz, *Laser-tissue interactions: fundamentals and applications*, Springer, Berlin (1996) [doi:10.1007/978-3-662-03193-3].

Oddziaływanie laserowe - PDT

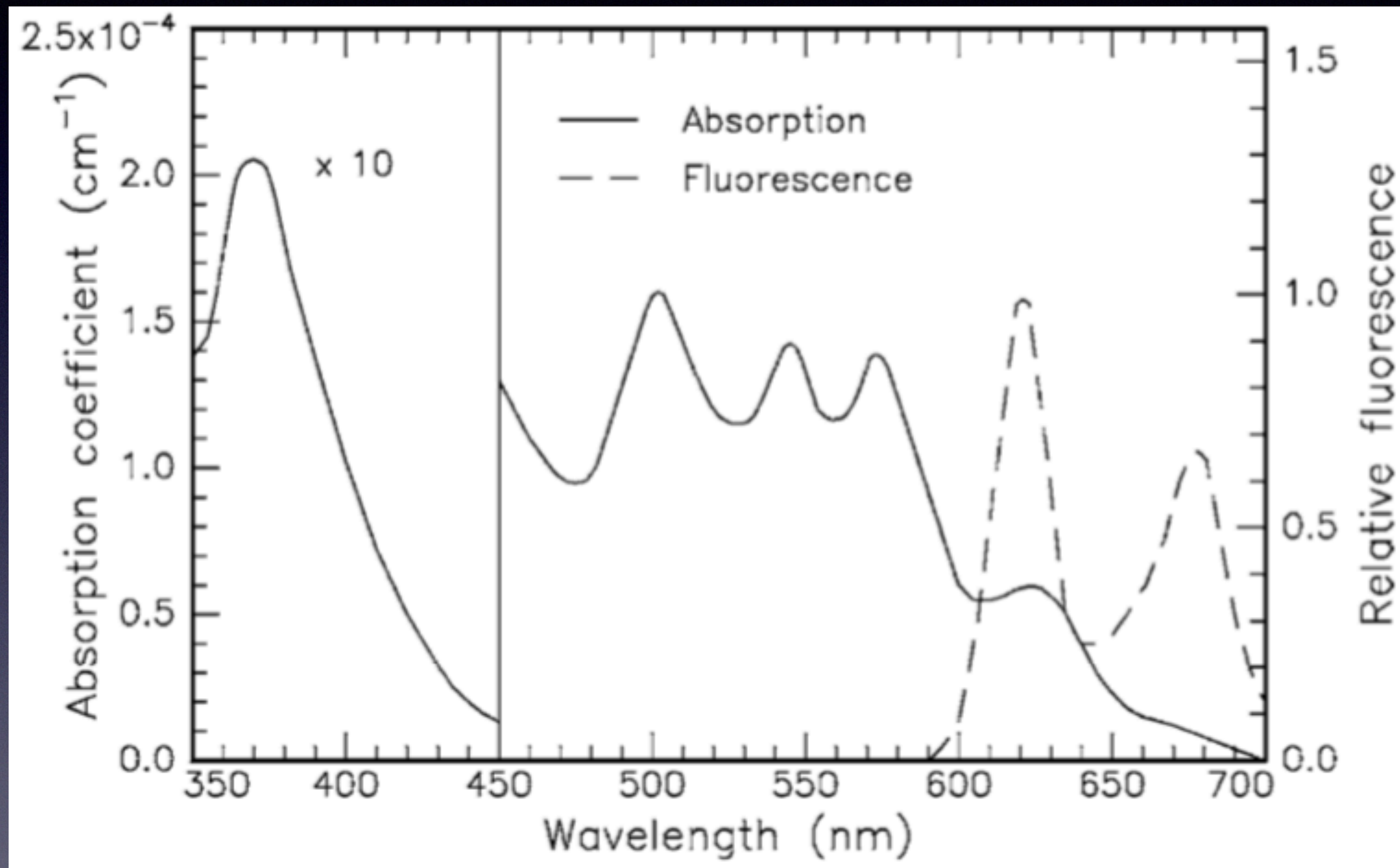


Methylene blue

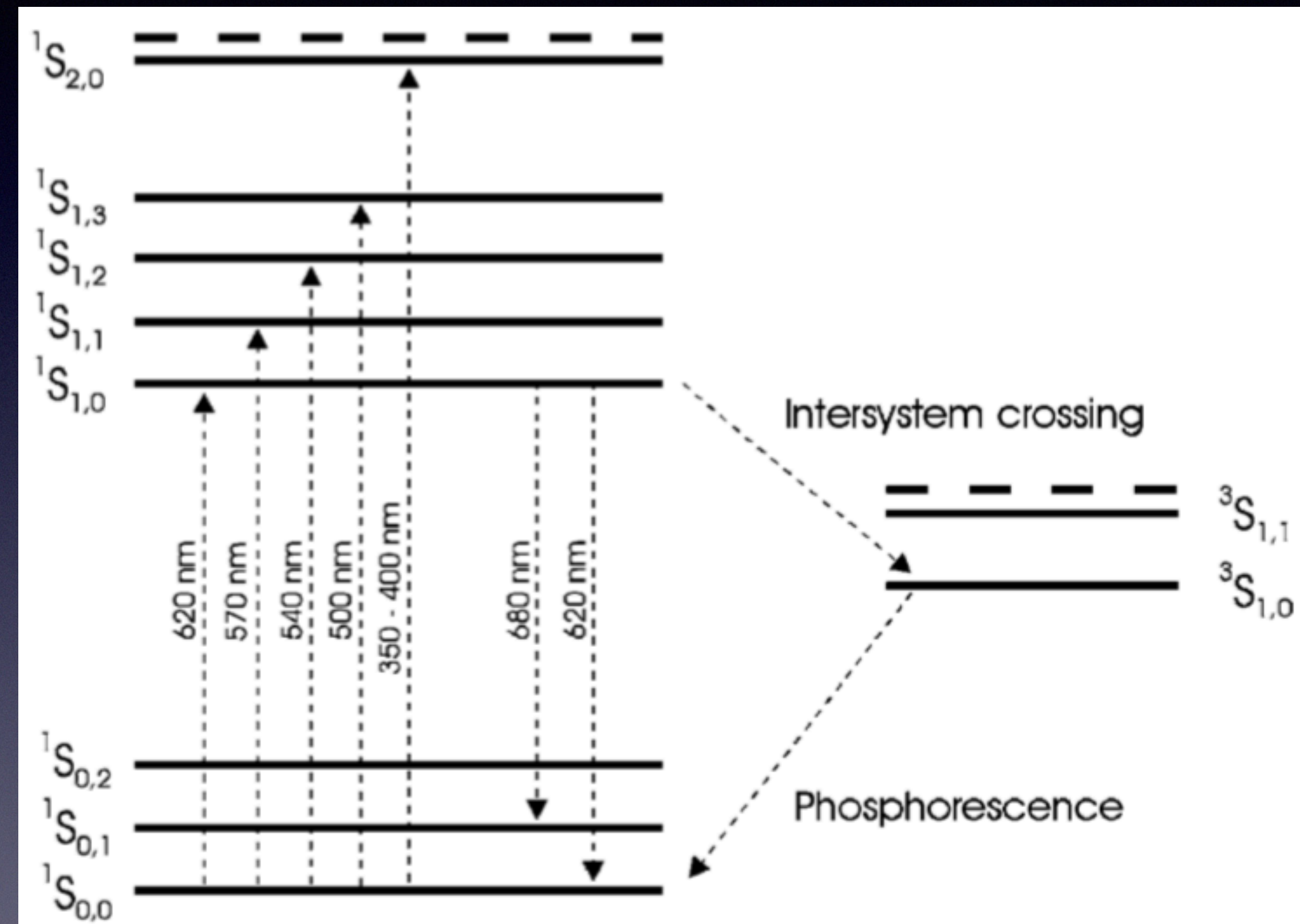


HpD ester

Oddziaływanie laserowe - PDT



Absorption and fluorescence spectra of hematoporphyrin derivative (HpD) dissolved in phosphate-buffered saline solution (PBS). Data according to Yamashita (1984)

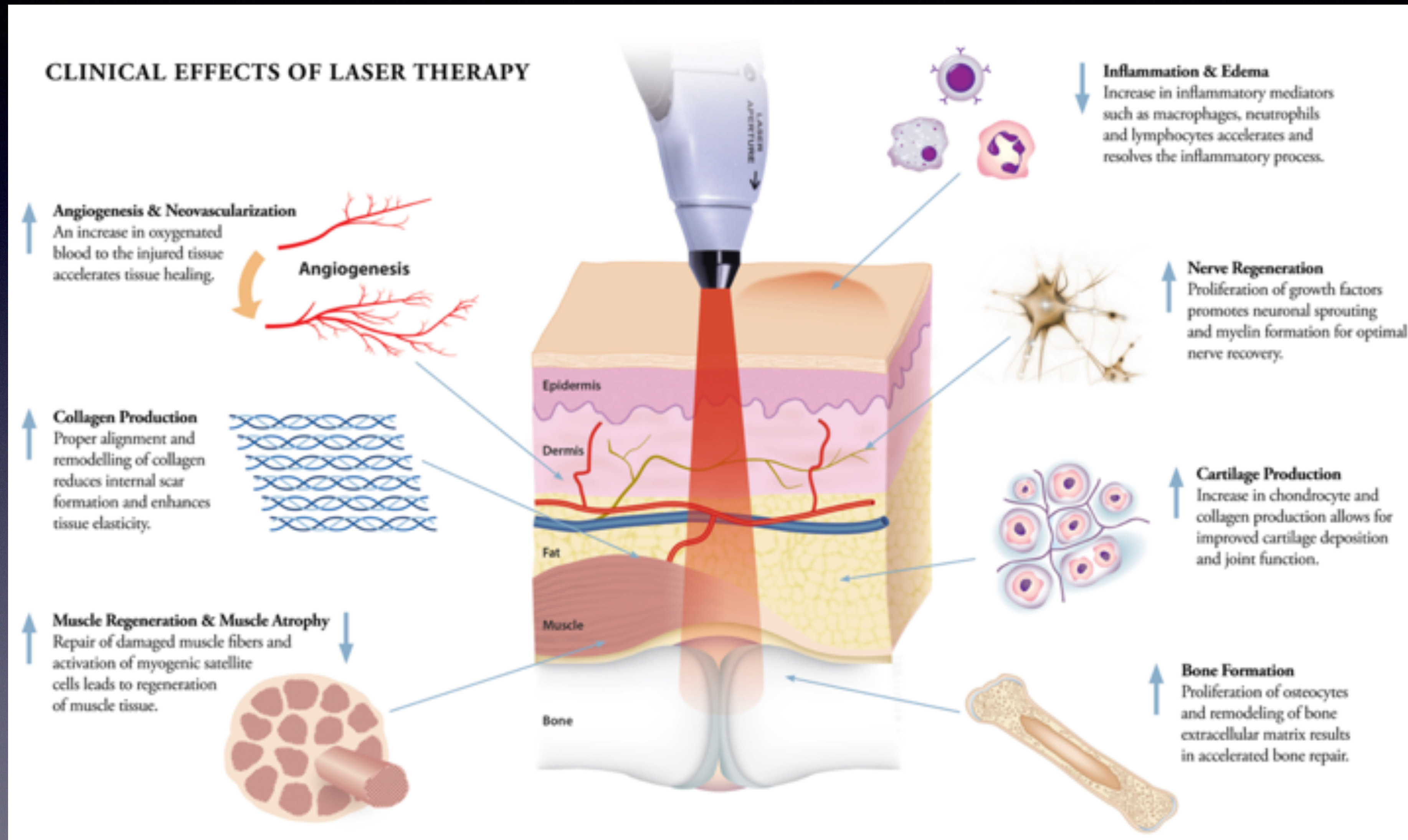


Energy level diagram of HpD. Singlet (1S) and triplet (3S) states are shown. Dashed lines indicate higher excited states

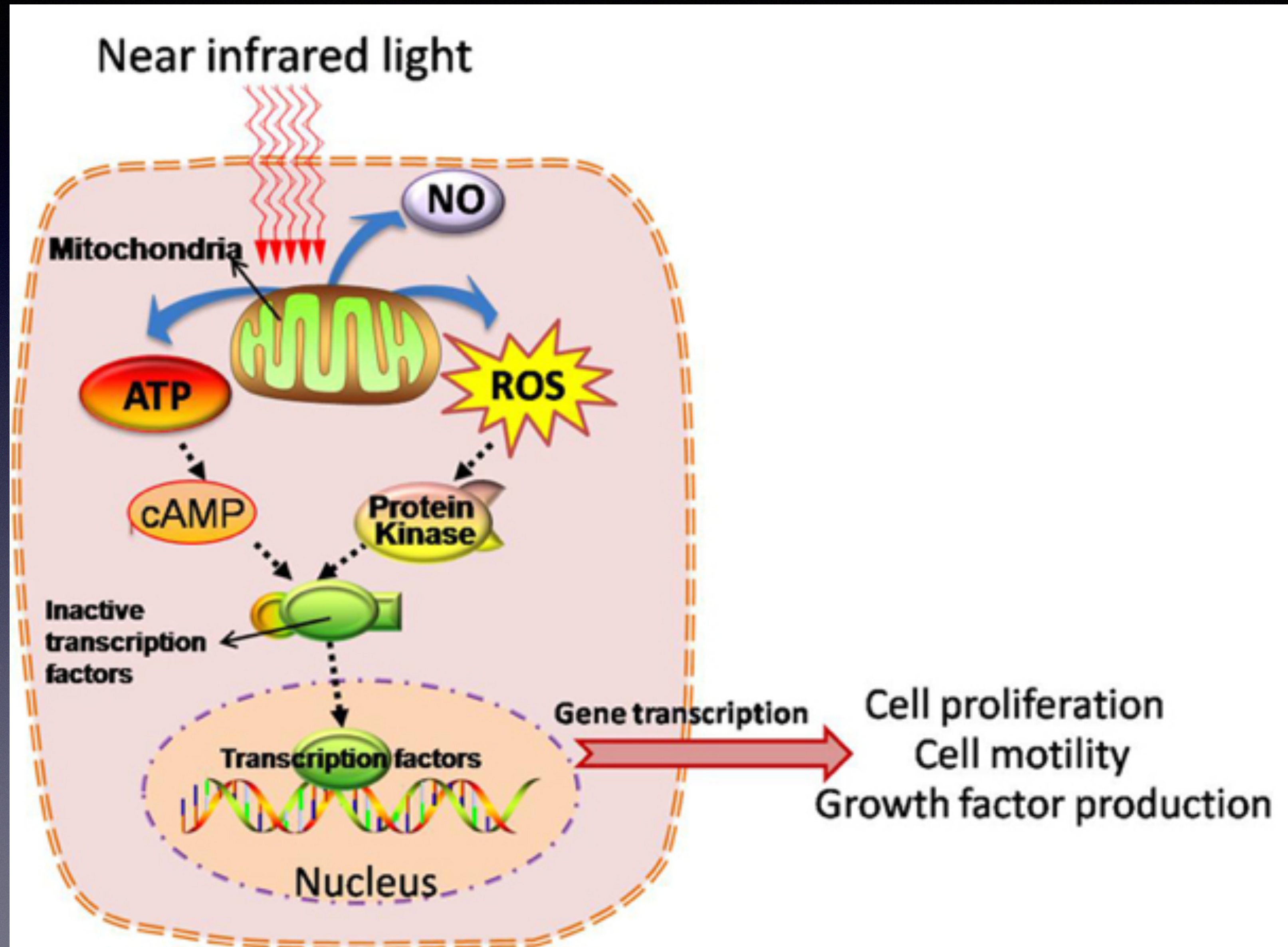
Wady PDT

- HpD - posiadają niski poziom absorpcji w zakresie czerwieni i podczerwieni, co ogranicza metodę terapii do nowotworów umiejscowionych na niewielkiej głębokości;
- gradient koncentracji HpD w komórkach zdrowych i nowotworowych może być skokowy;
- Konieczność izolacji pacjenta od światła zewnętrznego (podanie karotenoidów);
- Produkcja hematoporfiryn z krwi cielęcej jest obecnie kosztowna.

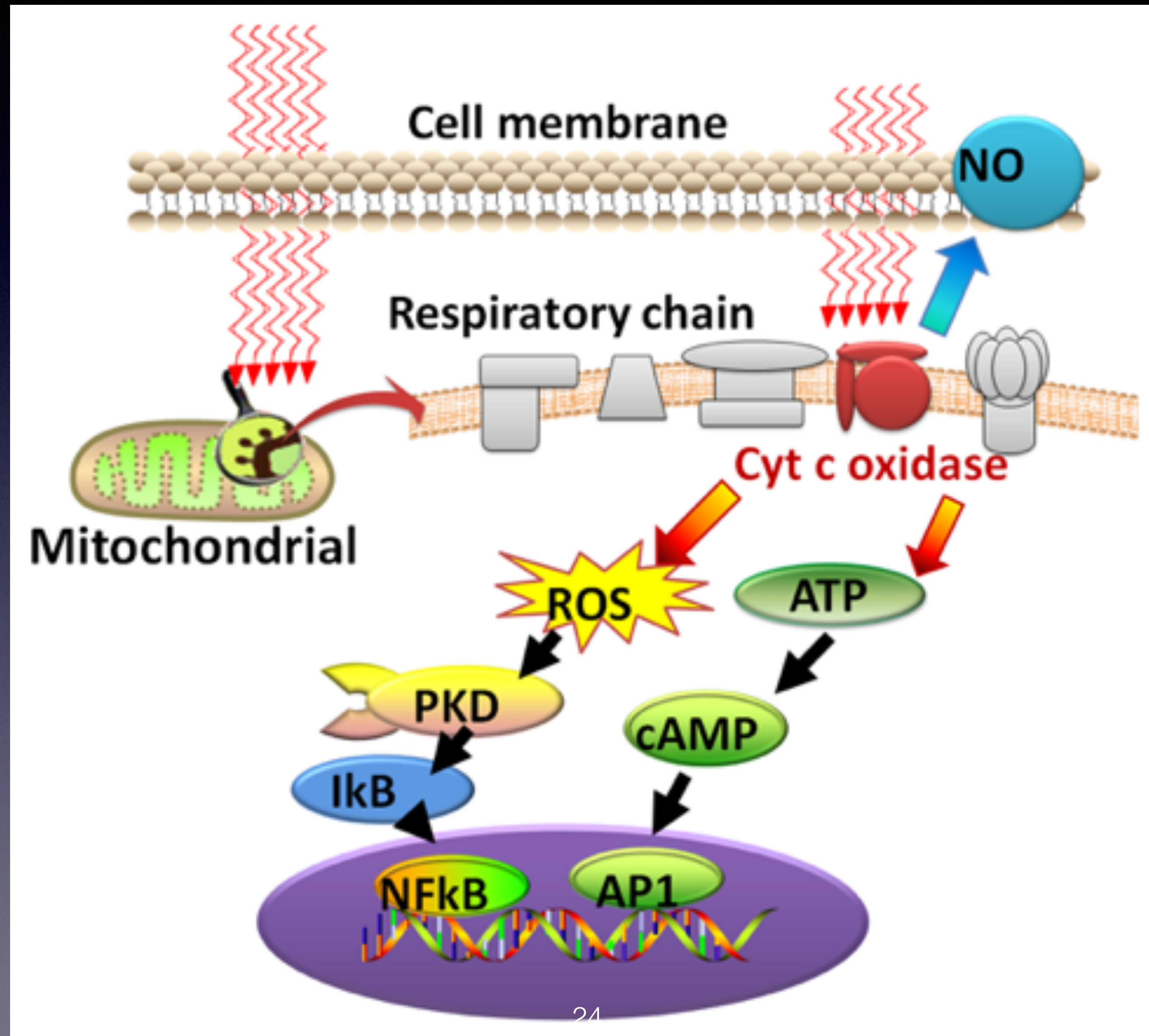
Oddziaływanie laserowe - biostymulacja



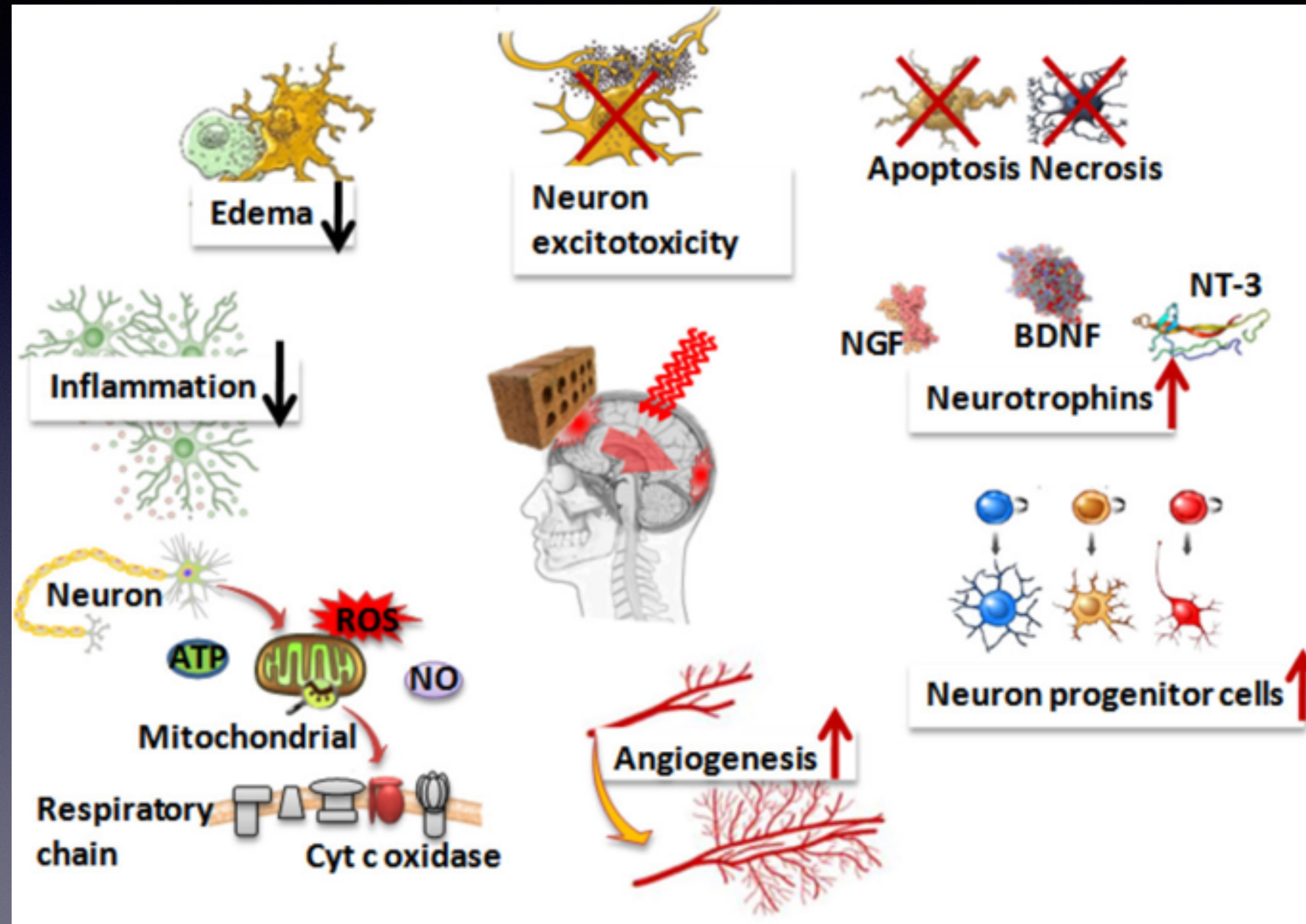
Oddziaływanie laserowe - biostymulacja



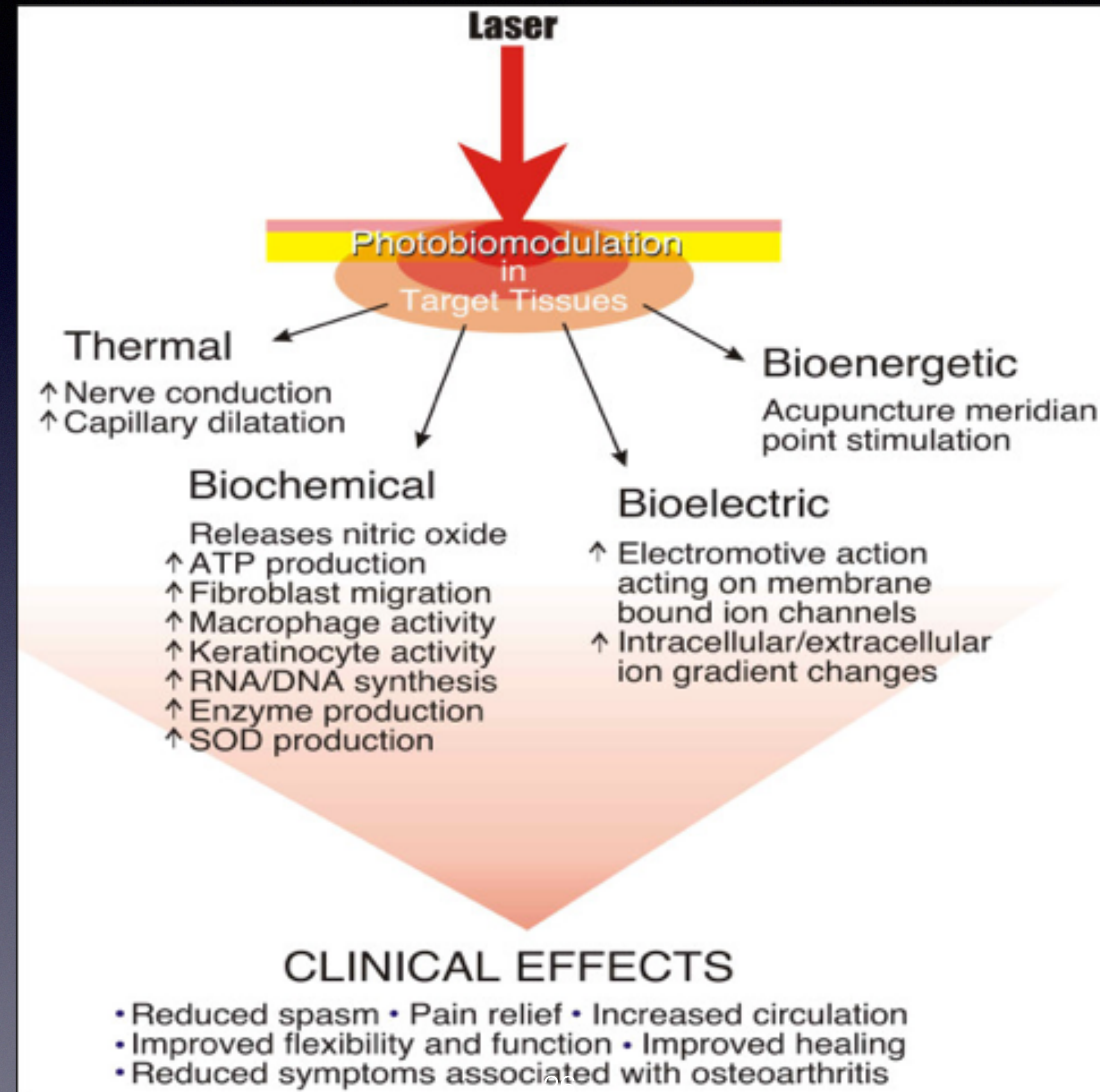
Oddziaływanie laserowe - biostymulacja



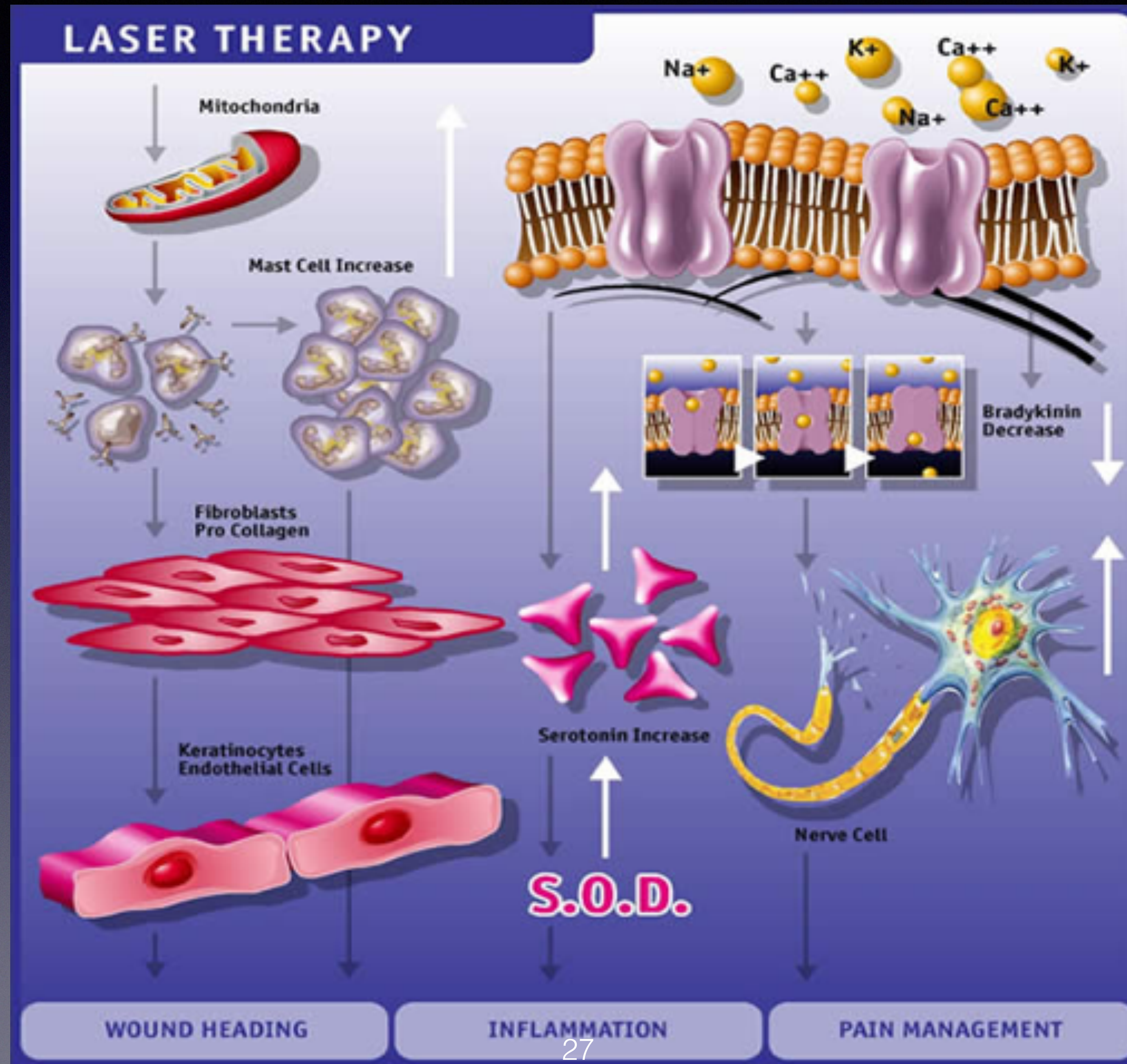
Oddziaływanie laserowe - biostymulacja











Oddziaływanie laserowe - biostymulacja



Oddziaływanie laserowe - biostymulacja

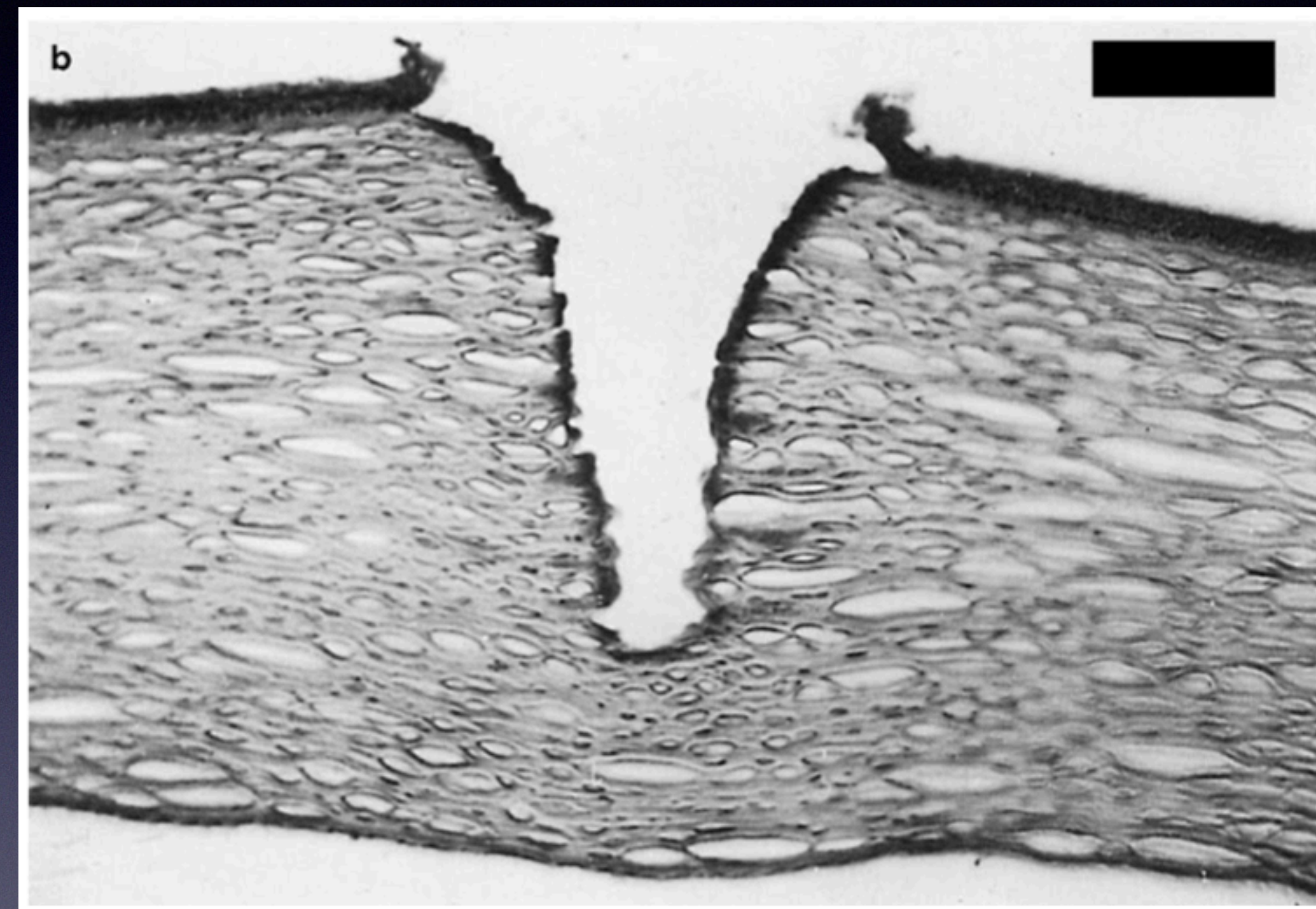


Oddziaływanie laserowe - biostymulacja

MOLECULE	BIOLOGICAL EFFECTS	CLINICAL BENEFITS
Growth Factors BDNF, GDNF, bFGF, IGF-I, KGF, PDGF, TGF- β , VEGF	 <ul style="list-style-type: none">• Proliferation• Differentiation	 <ul style="list-style-type: none">• Normal tissue regeneration• Reduces scarring• Rapid recovery
Interleukins IL-1 α , IL-6, IL-8, IL-2, IL-4	 <ul style="list-style-type: none">• Migration• Immunological activation	 <ul style="list-style-type: none">• Resolves difficult infections• Improves inflammatory response
Inflammatory Cytokines PGE2, COX-2, IL-1 β , TNF- α	 <ul style="list-style-type: none">• Inhibition of inflammation	 <ul style="list-style-type: none">• Reduces pain and swelling• Improves range of motion• Functional recovery
Small Molecules ATP, cGMP, ROS, Ca ²⁺ , NO	 <ul style="list-style-type: none">• Angiogenesis• Cell signalling	 <ul style="list-style-type: none">• Restores normal vasculature• Resolves chronic ulcers

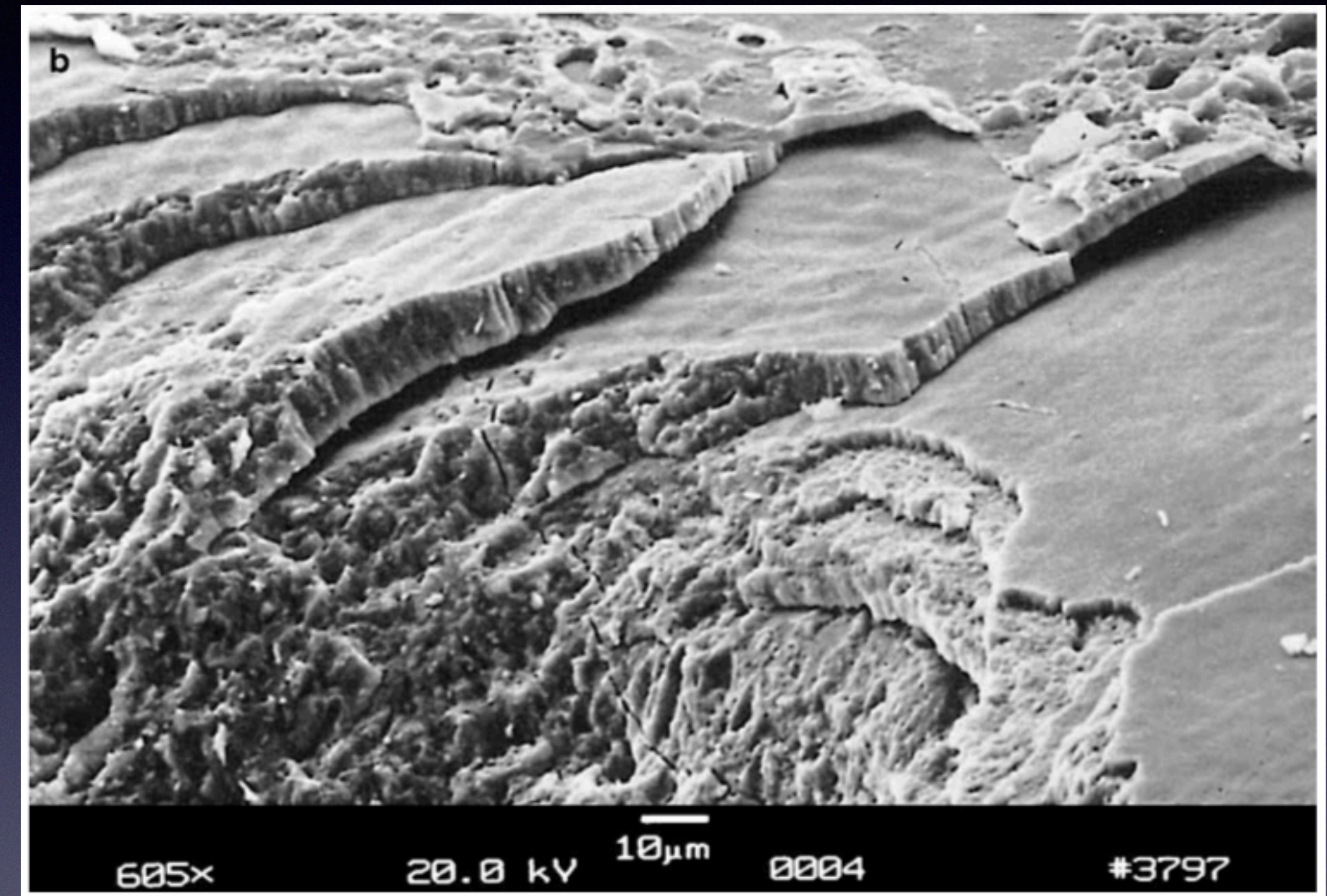
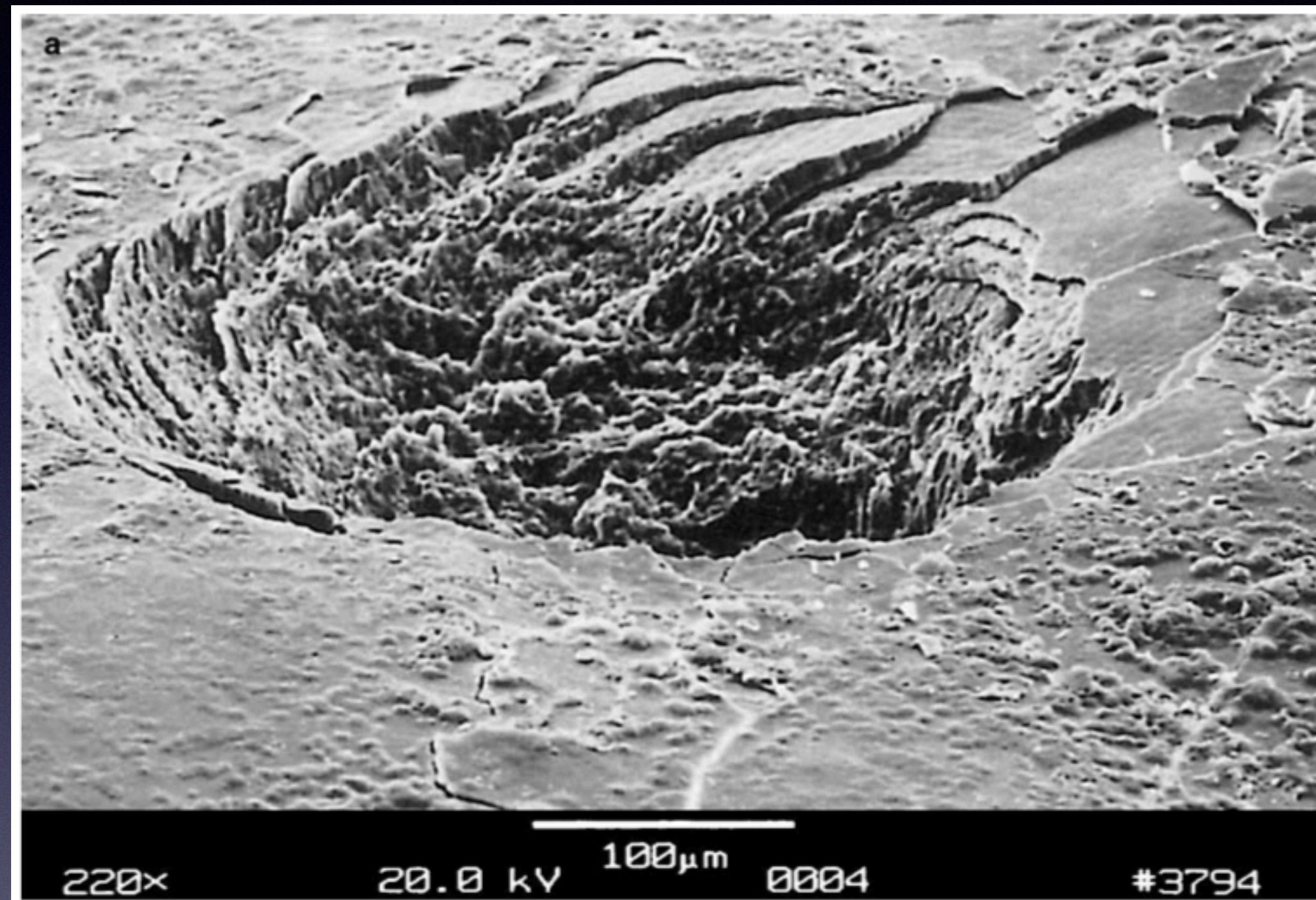
†Adapted from Xuejuan et al (2009) J of Biomed Sci

Oddziaływanie termiczne - koagulacja



Uterine tissue of a wistar rat coagulated with a CW Nd:YAG laser (power: 10 W, bar: 80 μm). Photograph kindly provided by Dr. Kurek (Heidelberg). (b) Human cornea coagulated with 120 pulses from an Er:YAG laser (pulse duration: 90 μs , pulse energy: 5 mJ, repetition rate: 1 Hz, bar: 100 μm)

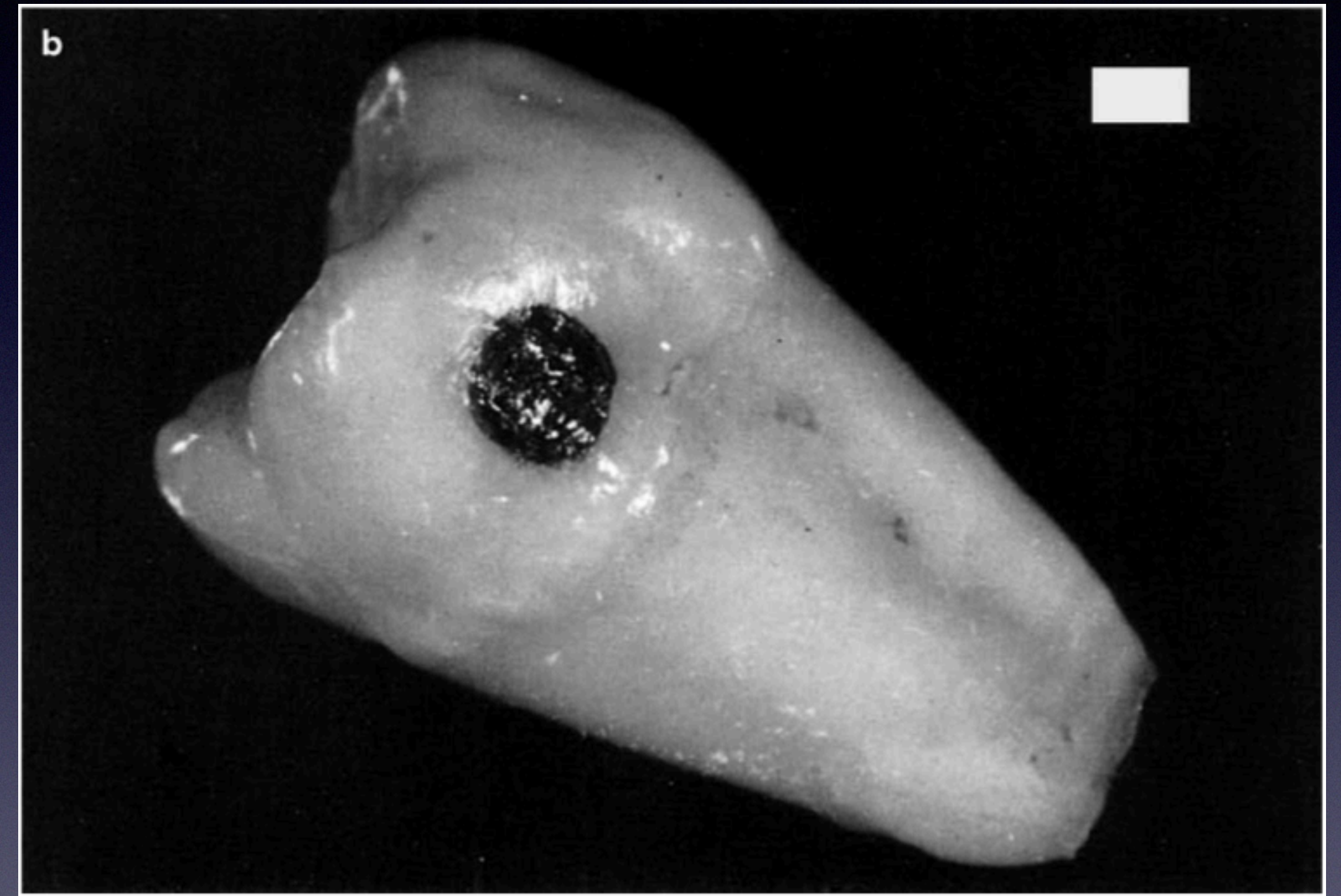
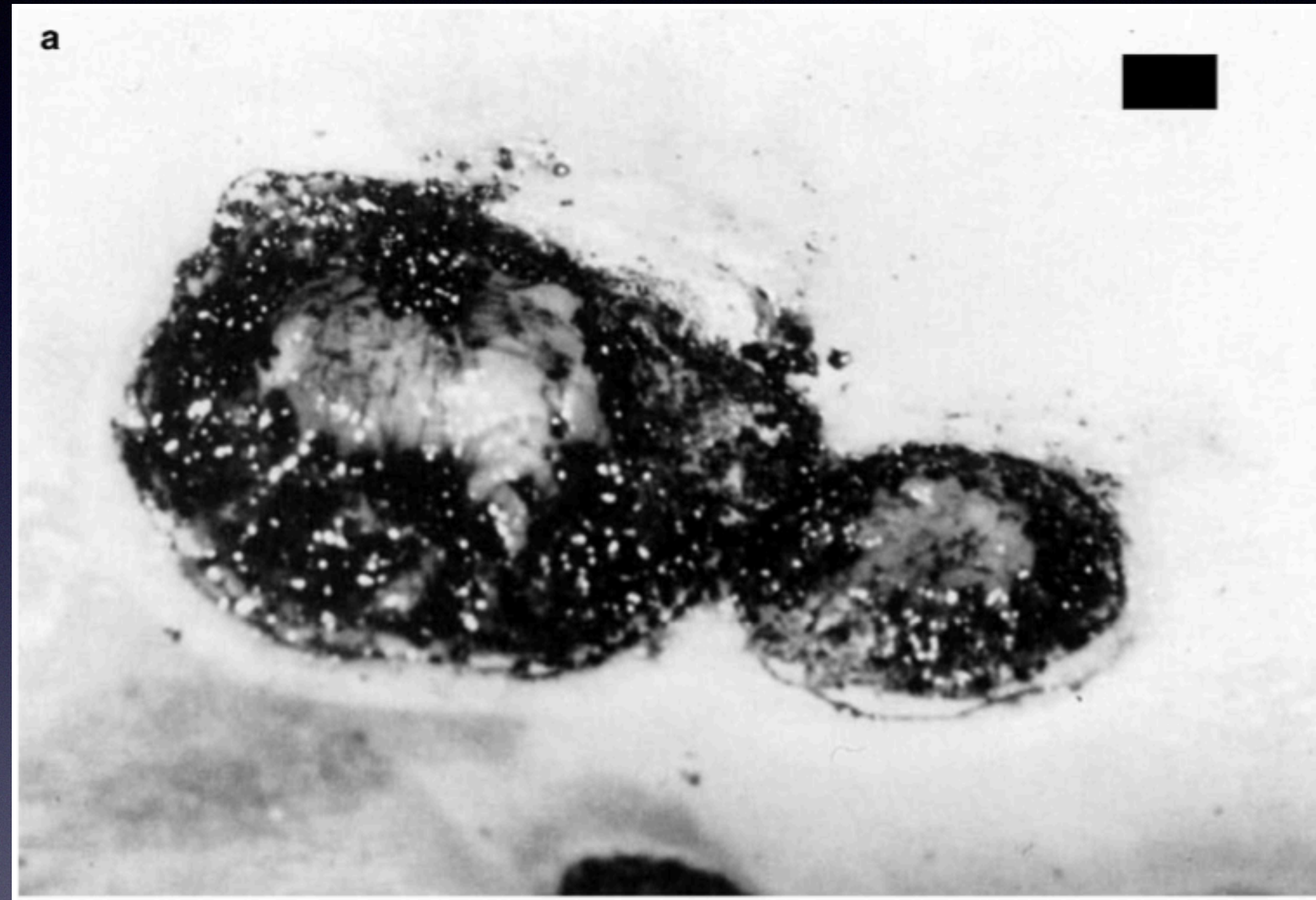
Oddziaływanie termiczne - odparowanie



(a) Human tooth vaporized with 20 pulses from an Er:YAG laser (pulse duration: 90 μ s, pulse energy: 100 mJ, repetition rate: 1 Hz). (b) Enlargement showing the edge of ablation

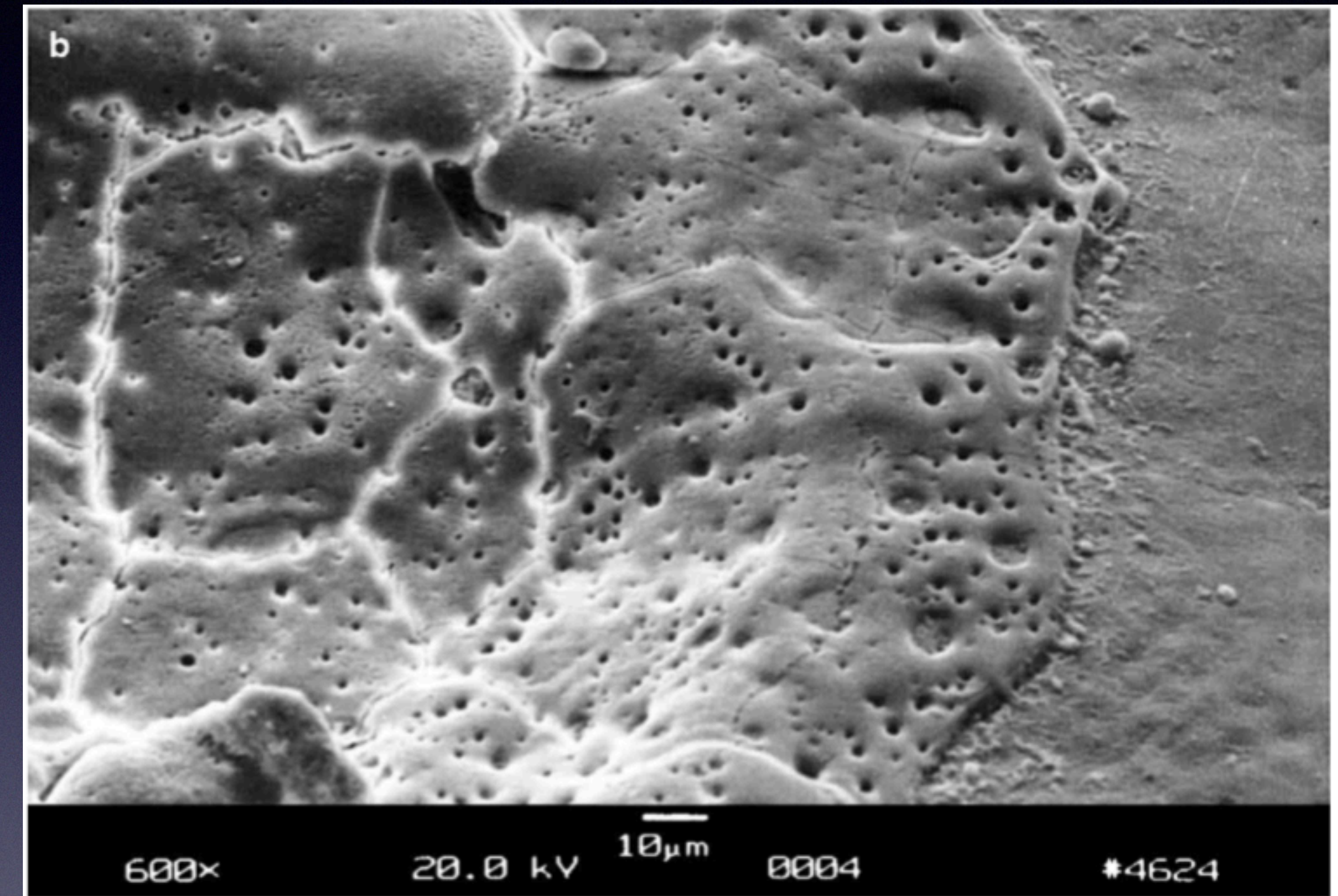
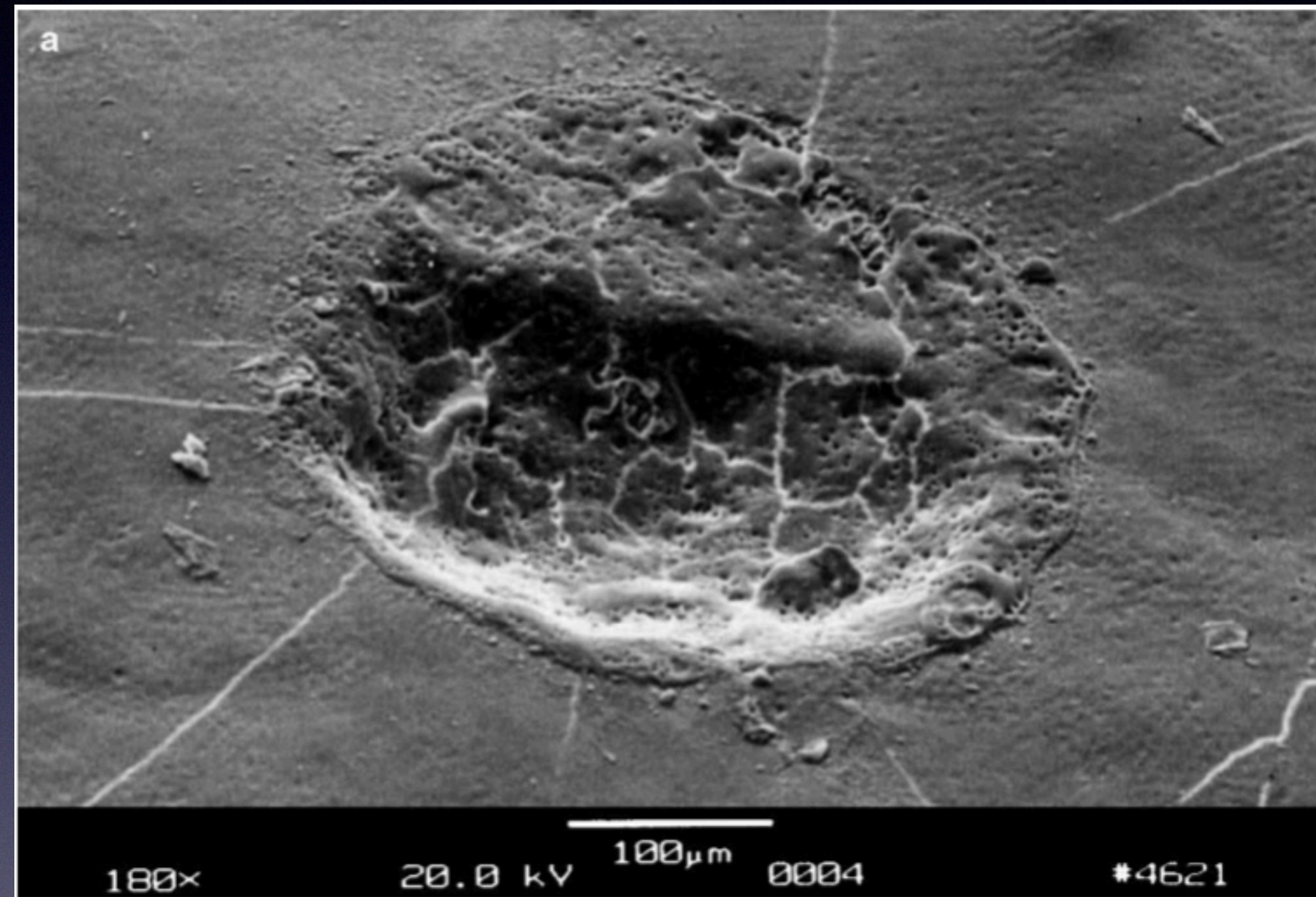
Efekt termomechaniczny

Oddziaływanie termiczne - carbonization



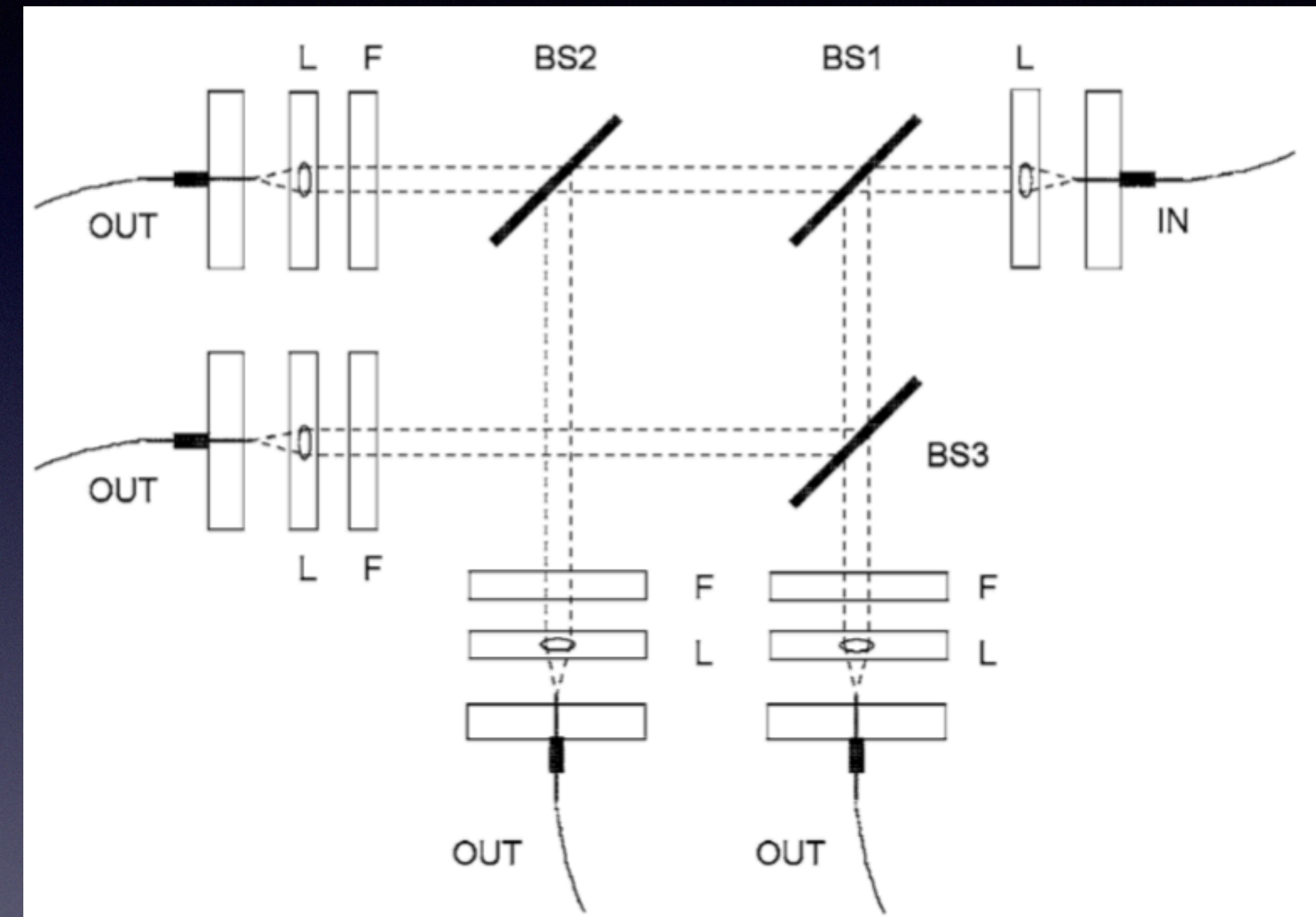
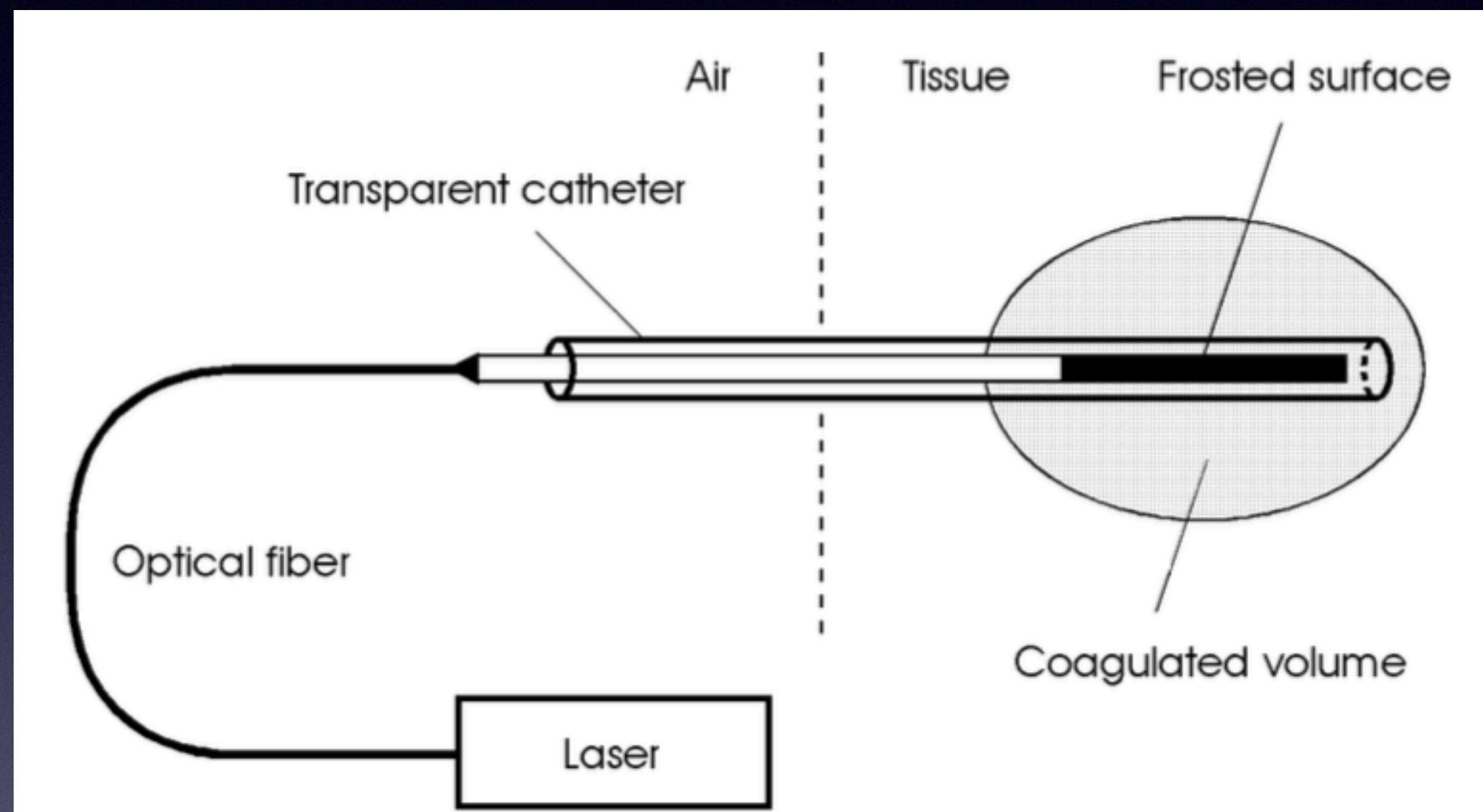
(a) Tumor metastases on human skin carbonized with a CW CO₂ laser (power: 40 W, bar: 1 mm). Photograph kindly provided by Dr. Kurek (Heidelberg). (b) Human tooth carbonized with a CW CO₂ laser (power: 1 W, bar: 1 mm)

Oddziaływanie termiczne - melting

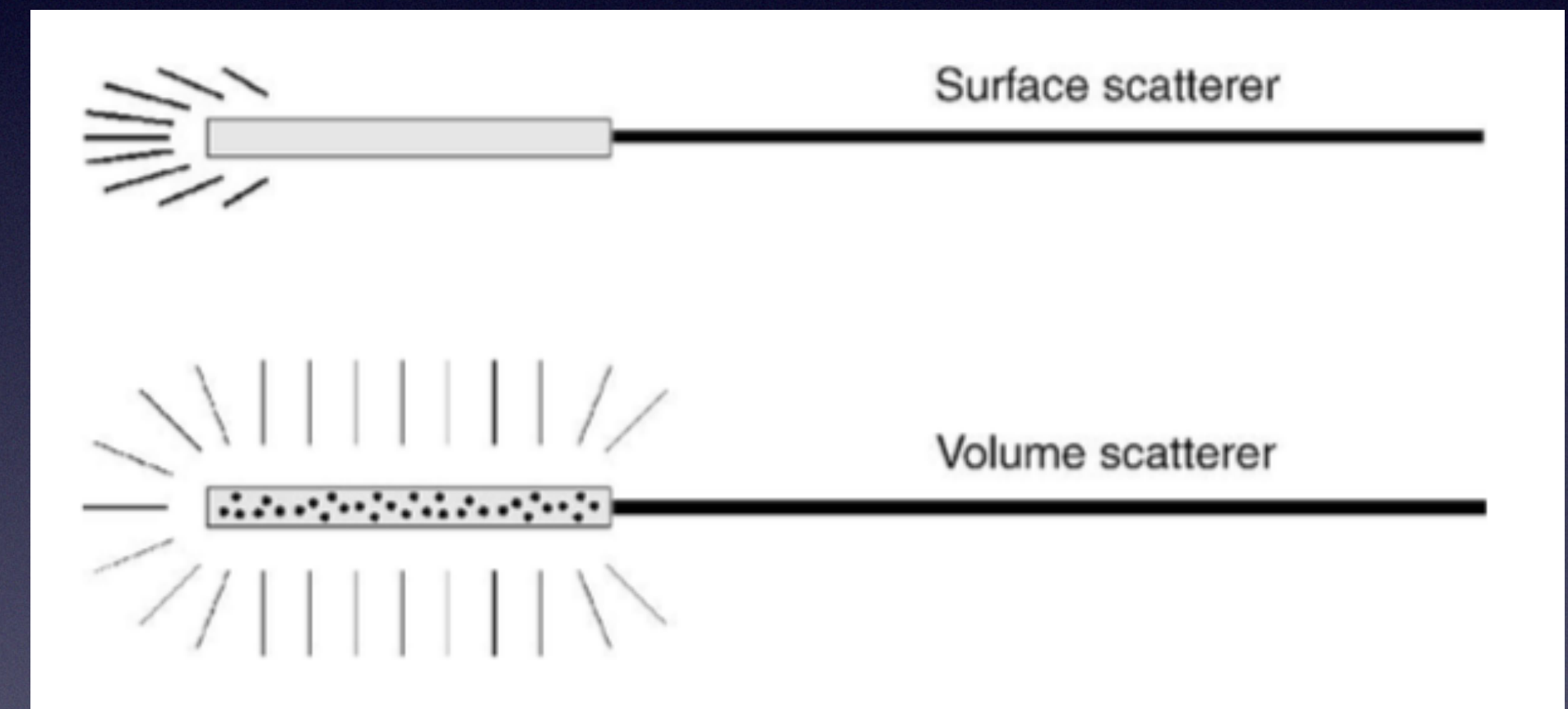
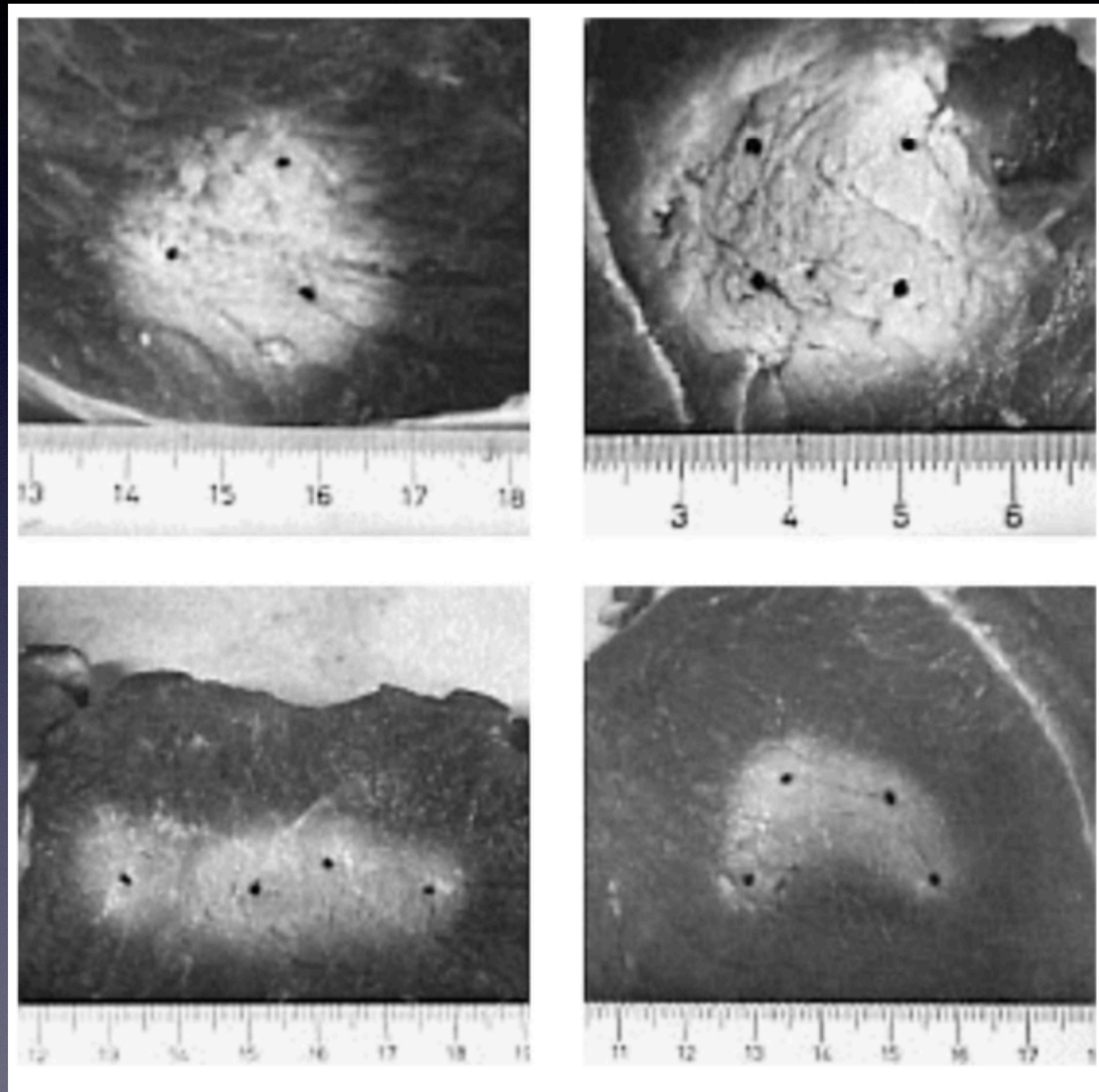


(a) Human tooth melted with 100 pulses from a Ho:YAG laser (pulse duration: 3.8 μ s, pulse energy: 18 mJ, repetition rate: 1 Hz). (b) Enlargement showing the edge of the melted zone

Laser-Induced Interstitial Thermotherapy (LITT)



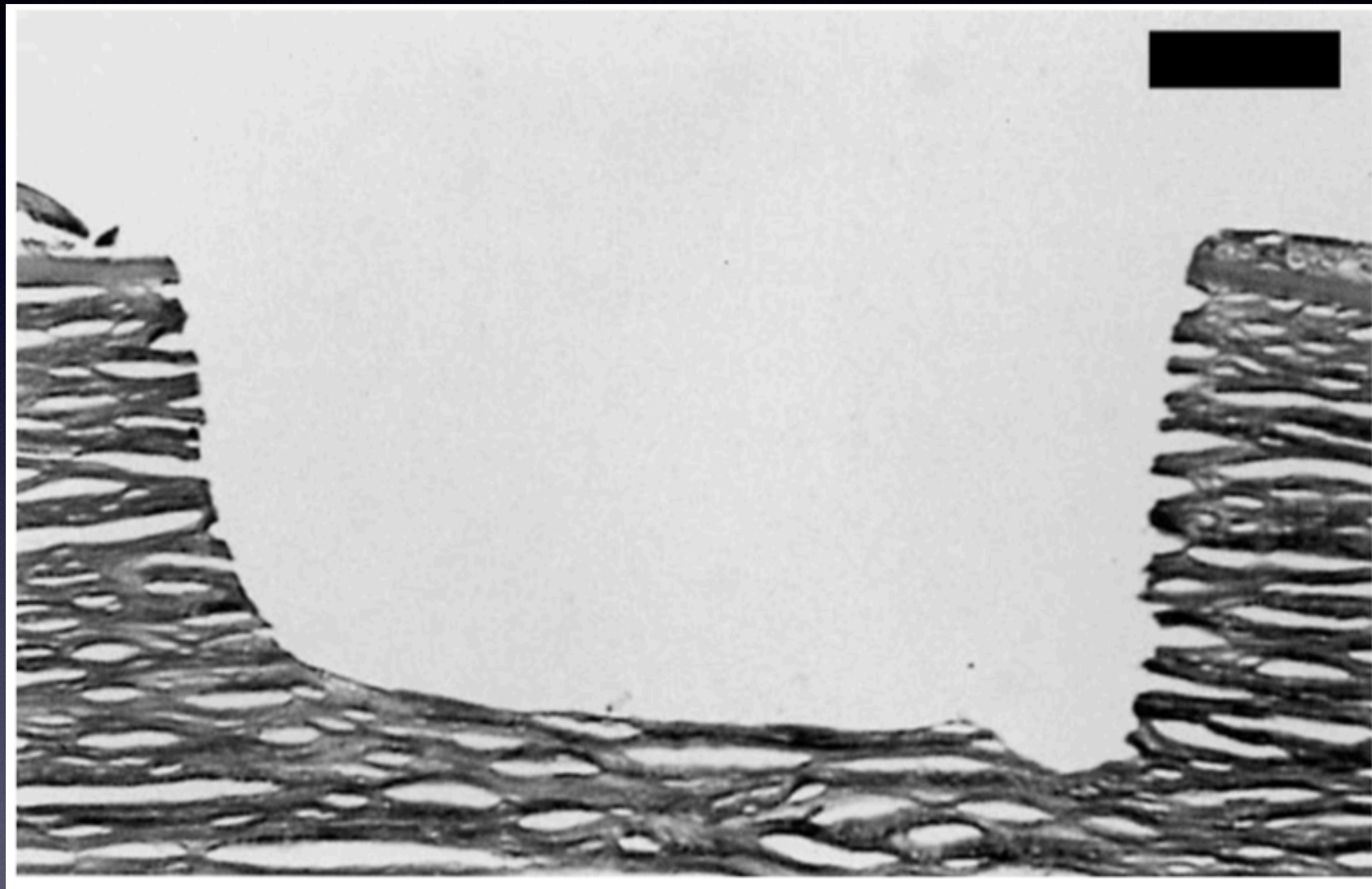
Laser-Induced Interstitial Thermotherapy (LITT)



Scattering profiles of surface scatterer and volume scatterer, respectively

Coagulations achieved in muscle tissue with several fibers (Nd:YAG laser, 4 W per fiber)

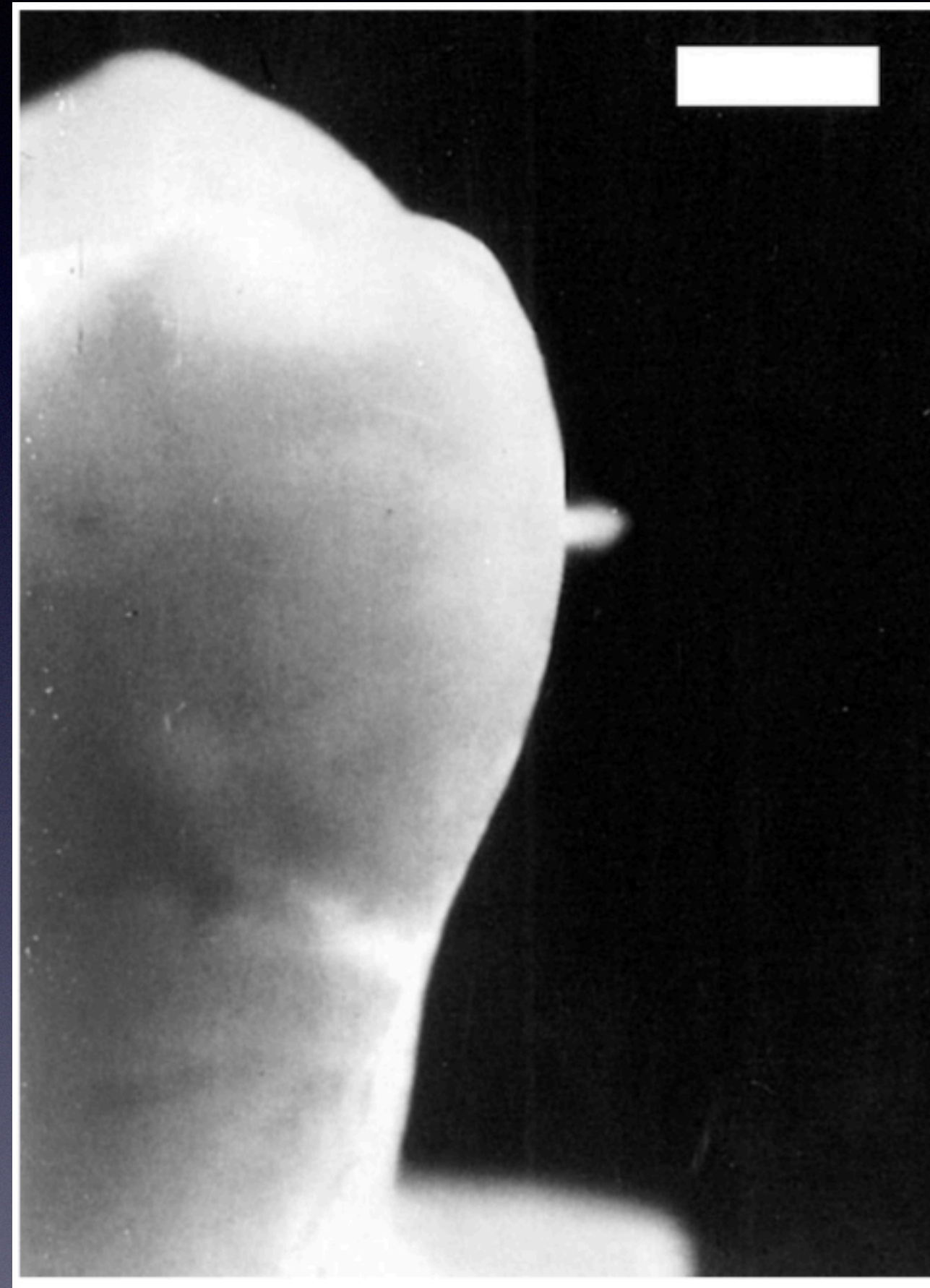
Fotoablacja



Photoablation of corneal tissue achieved with an ArF excimer laser (pulse duration: 14 ns, energy density: 180 mJ/cm², bar: 100 μm). Photograph kindly provided by Dr. Bende (Tübingen)

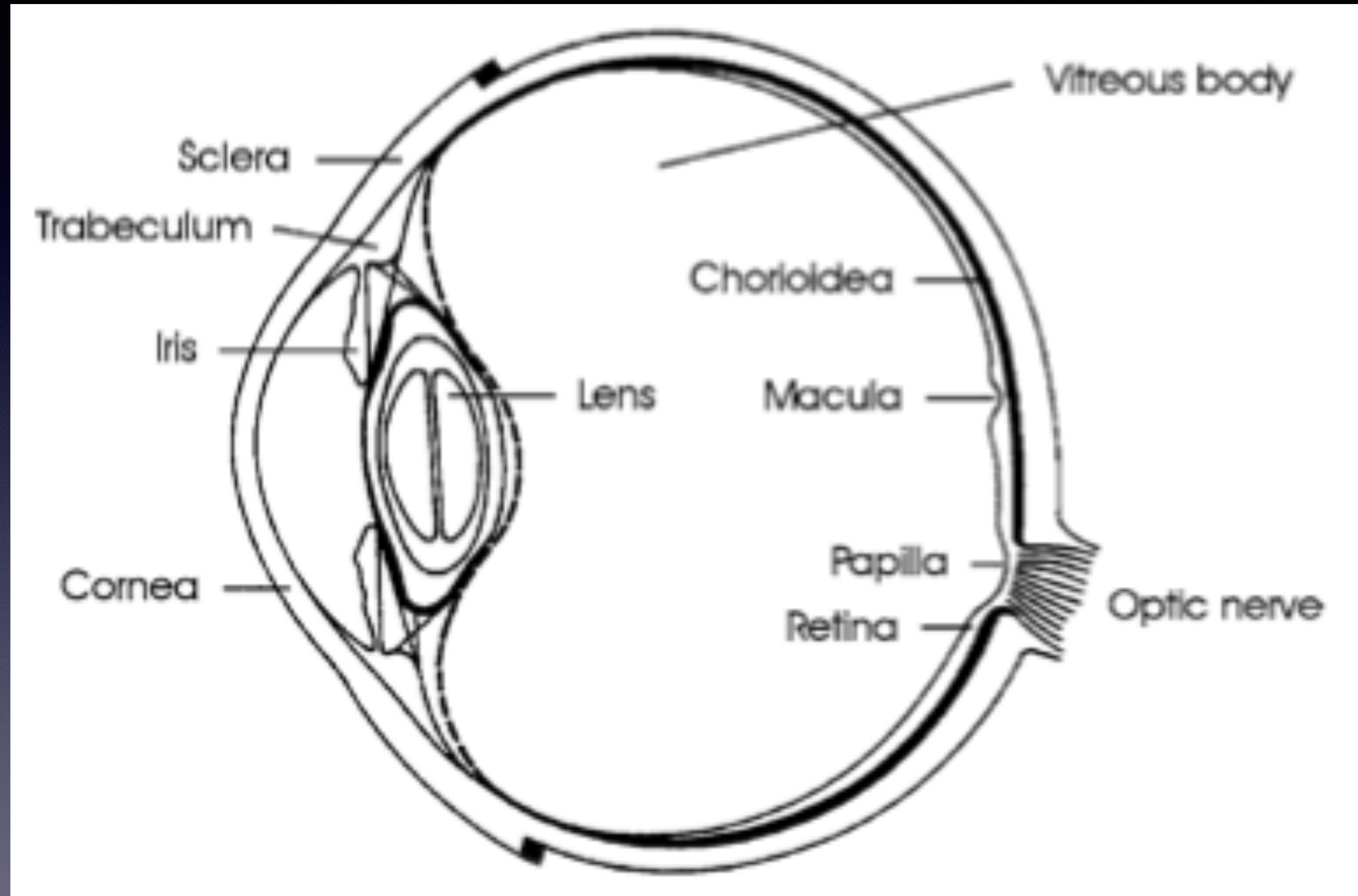
- excitation: $AB + h\nu \longrightarrow (AB)^*$,
- dissociation: $(AB)^* \longrightarrow A + B + E_{\text{kin}}$.

Ablacja indukowana plazmą



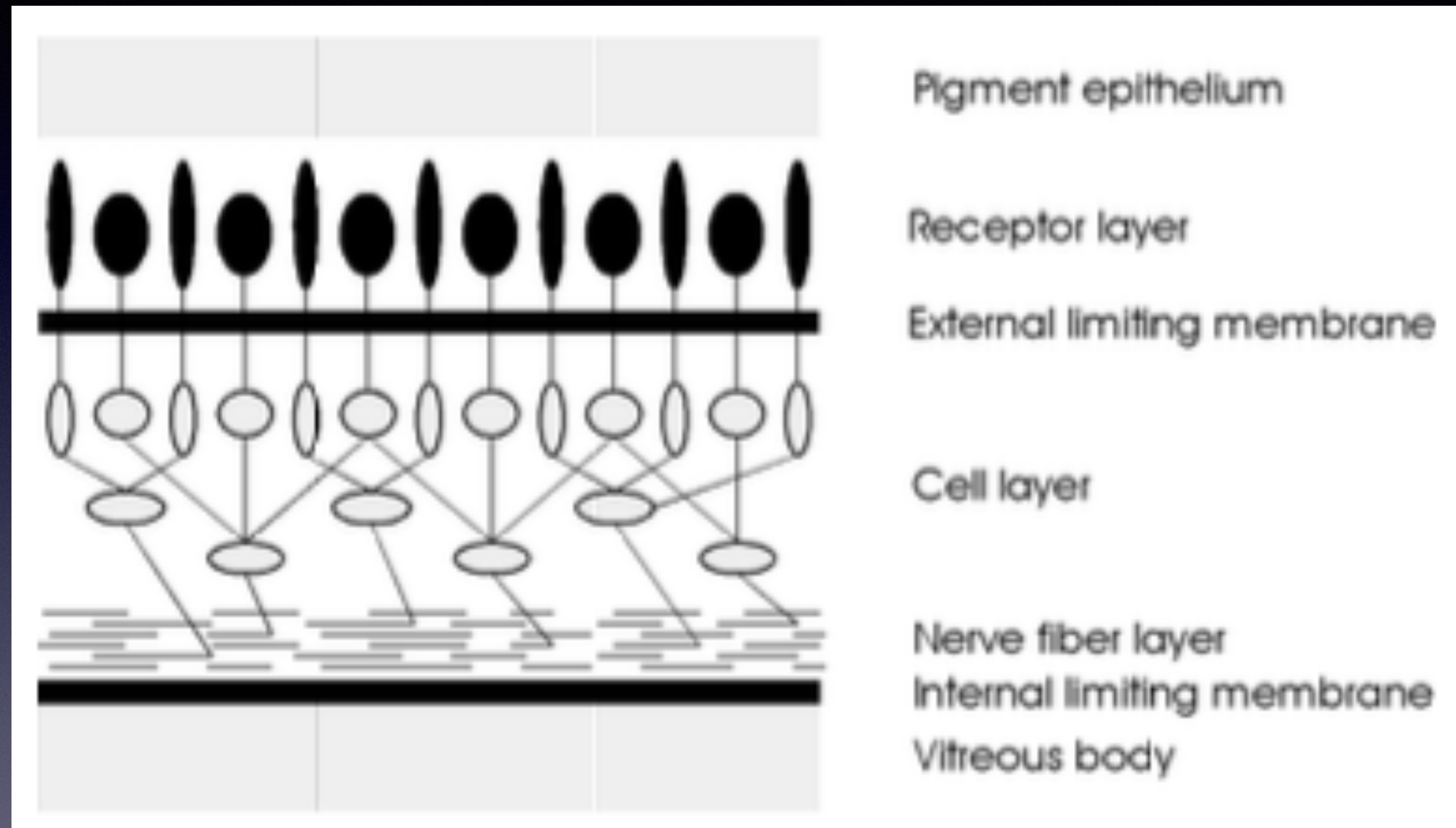
Laser-induced plasma sparking on tooth surface caused by a single pulse from a Nd:YLF laser (pulse duration: 30 ps, pulse energy: 1 mJ, focal spot size: 30 μm , bar: 1 mm). With these parameters, a power density of about $5 \times 10^{12} \text{ W/cm}^2$ is obtained

Okulistyka



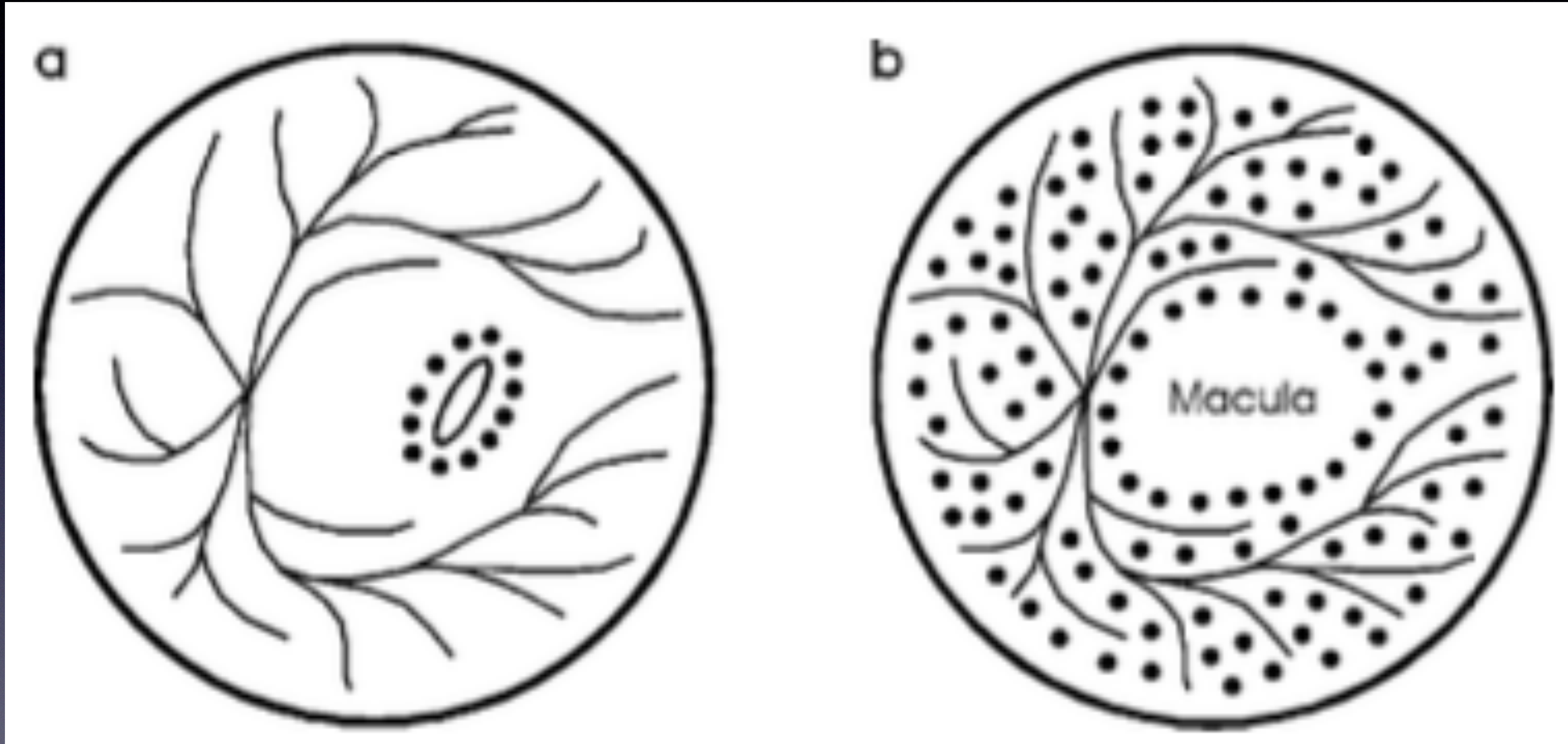
M. H. Niemz, *Laser-tissue interactions: fundamentals and applications*, Springer, Berlin (1996) [doi:10.1007/978-3-662-03193-3].

Siatkówka oka



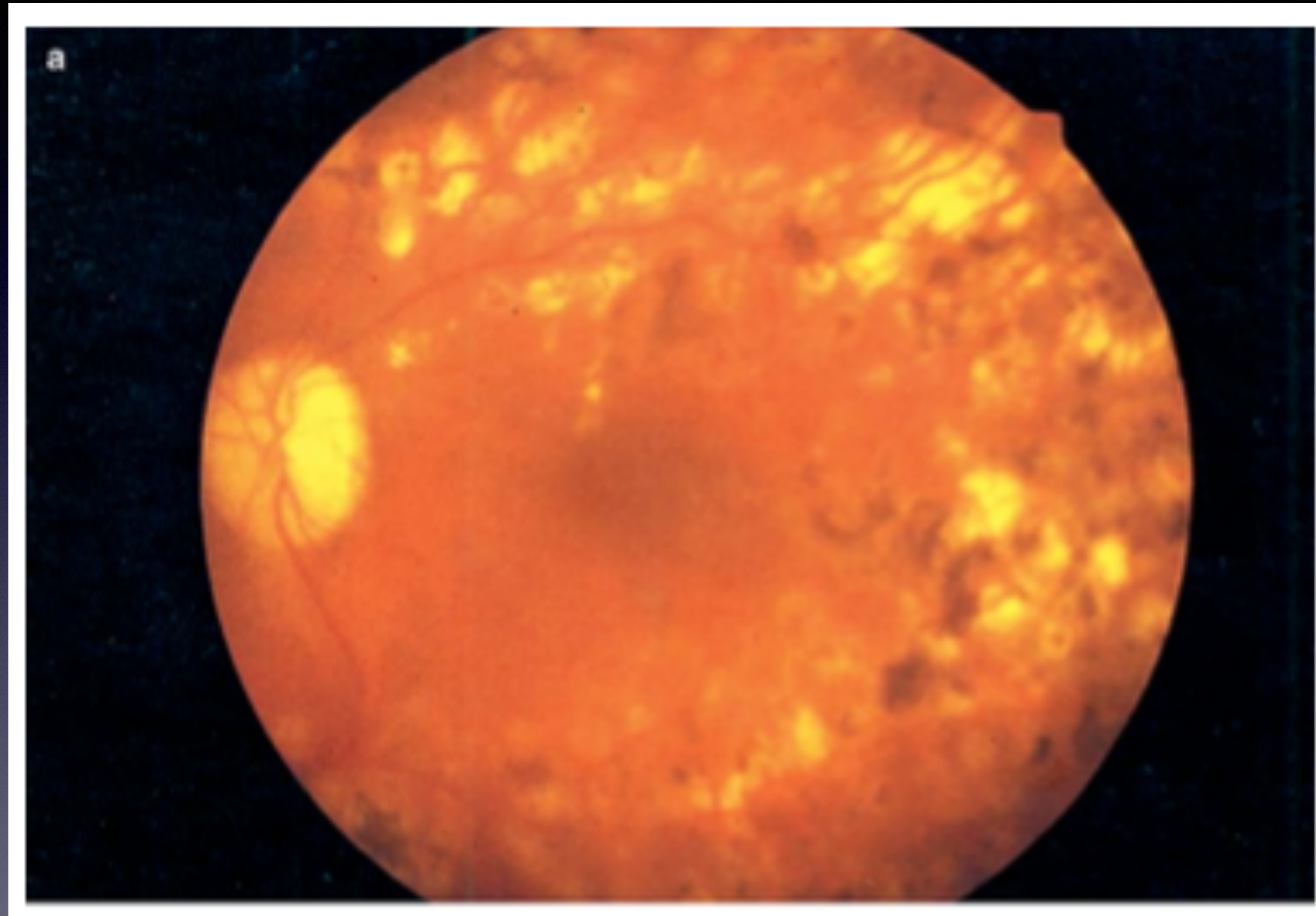
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Siatkówka oka



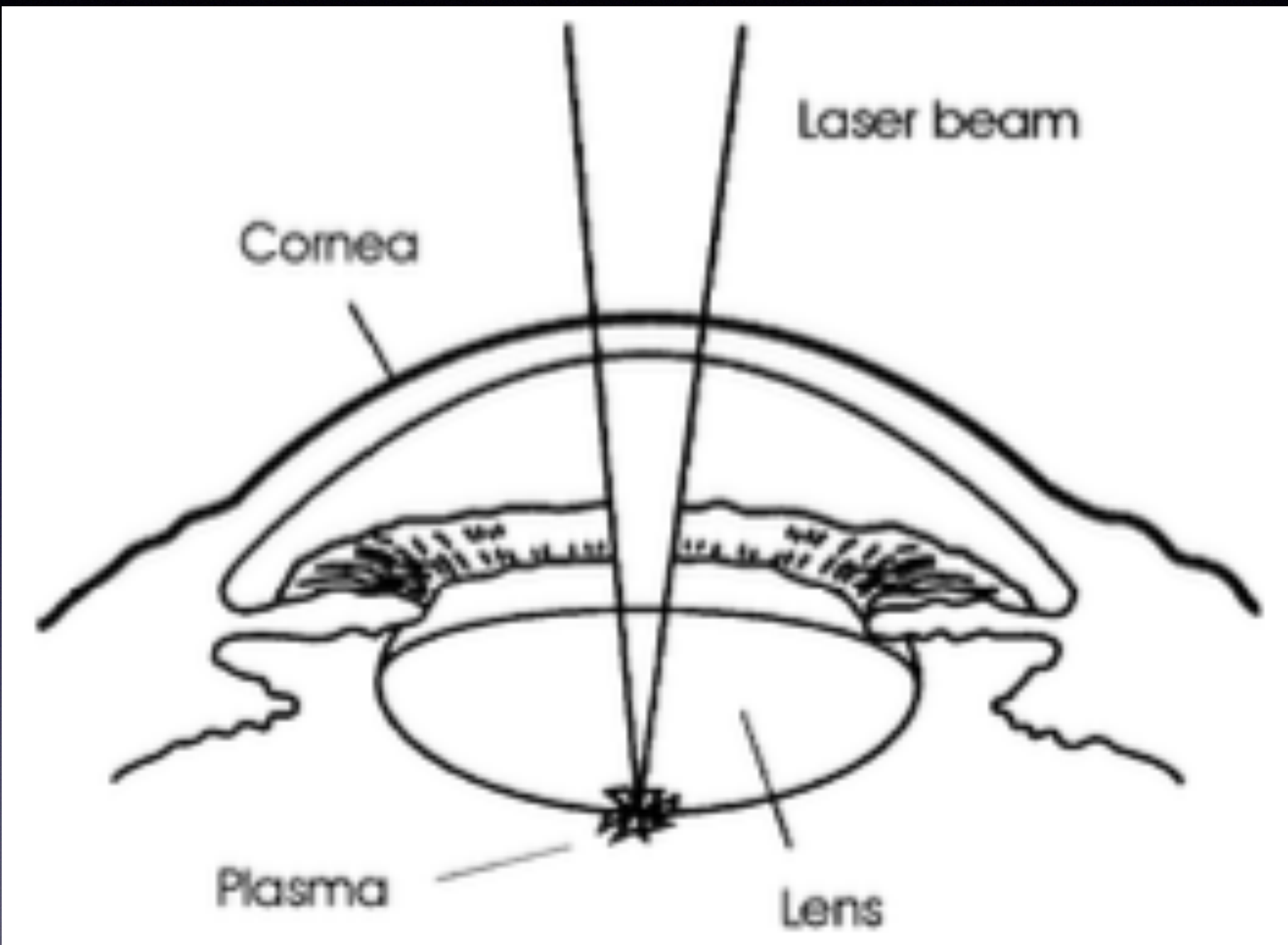
M. H. Niemz, *Laser-tissue interactions: fundamentals and applications*, Springer, Berlin (1996) [doi:10.1007/978-3-662-03193-3].

Siatkówka oka



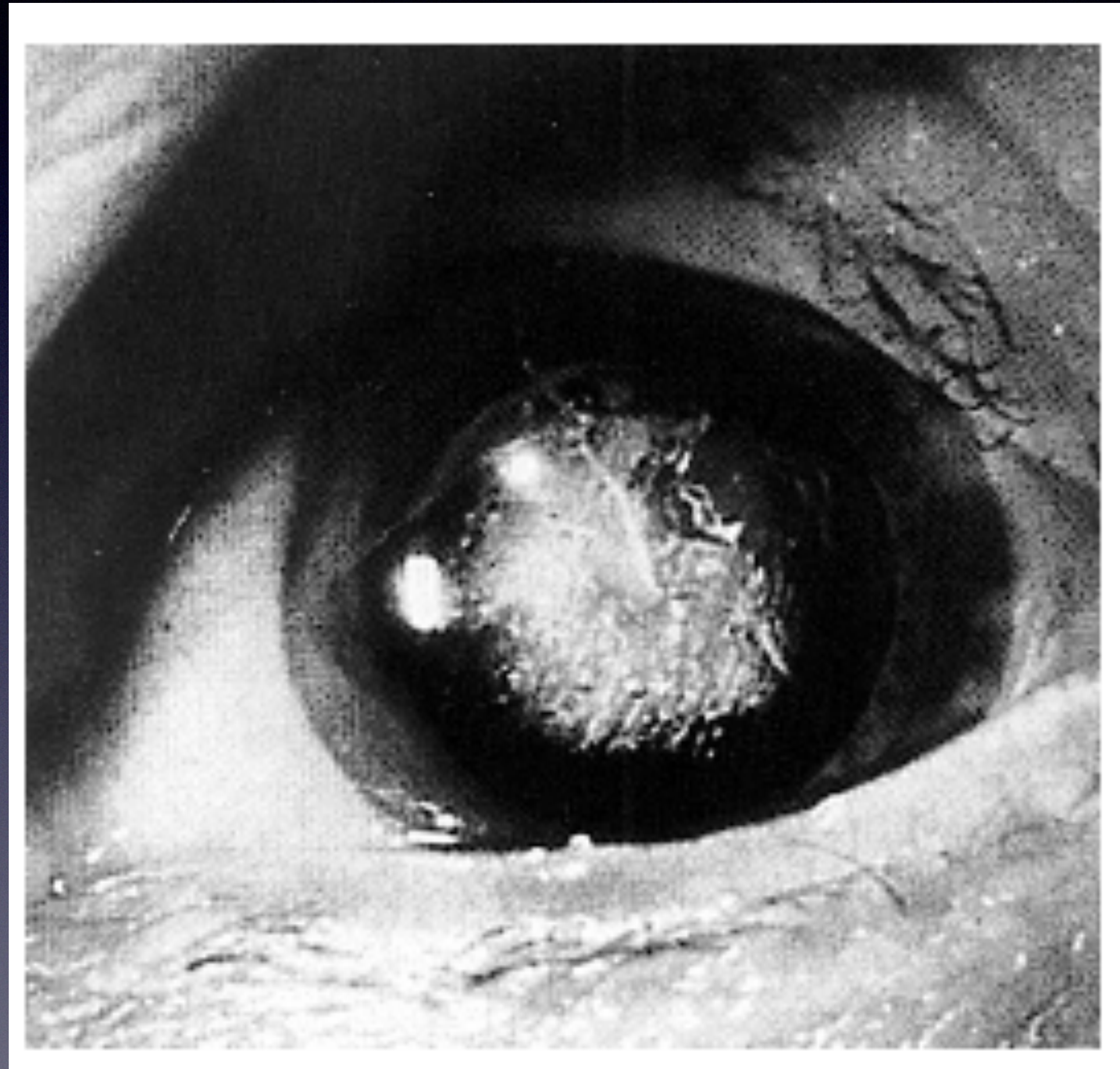
M. H. Niemz, *Laser-tissue interactions: fundamentals and applications*, Springer, Berlin (1996) [doi:10.1007/978-3-662-03193-3].

Soczewka oka



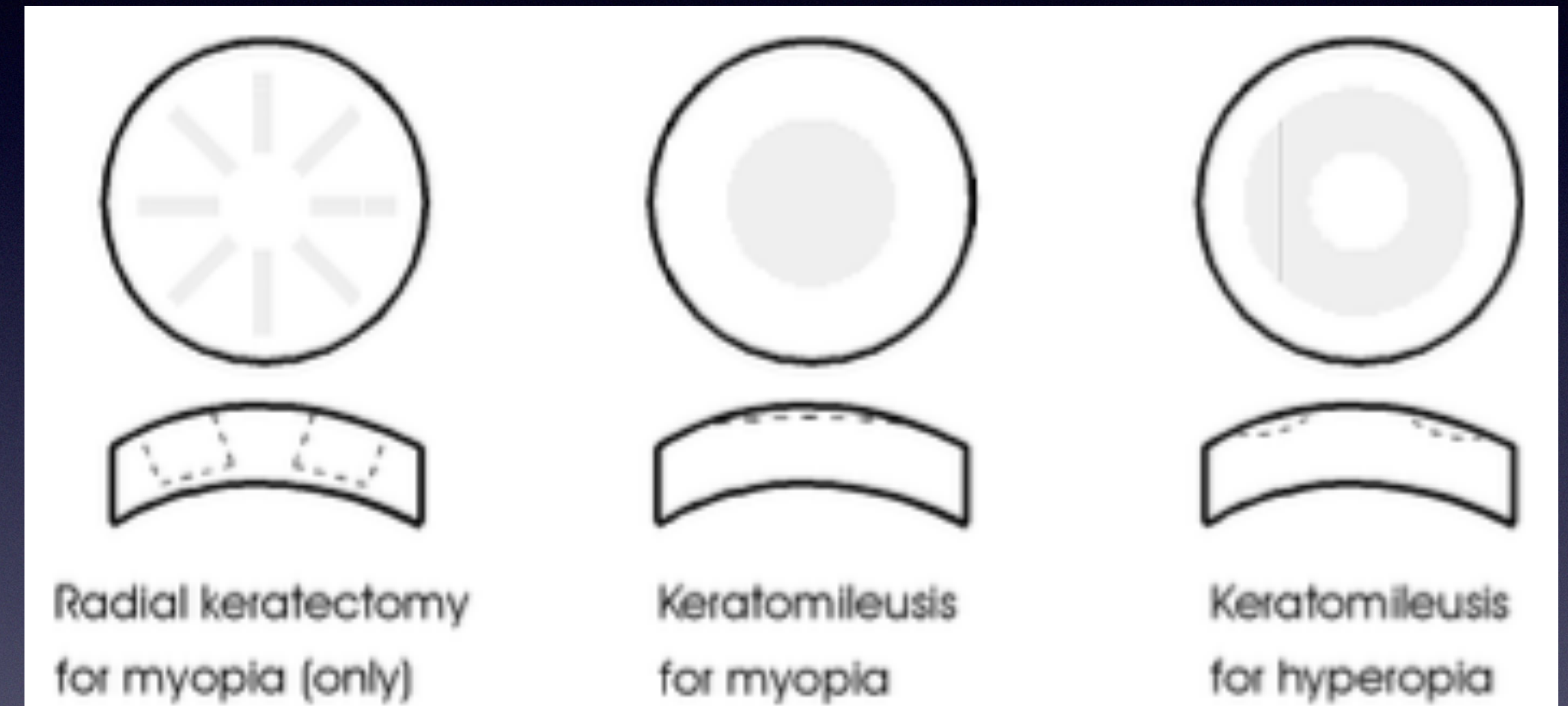
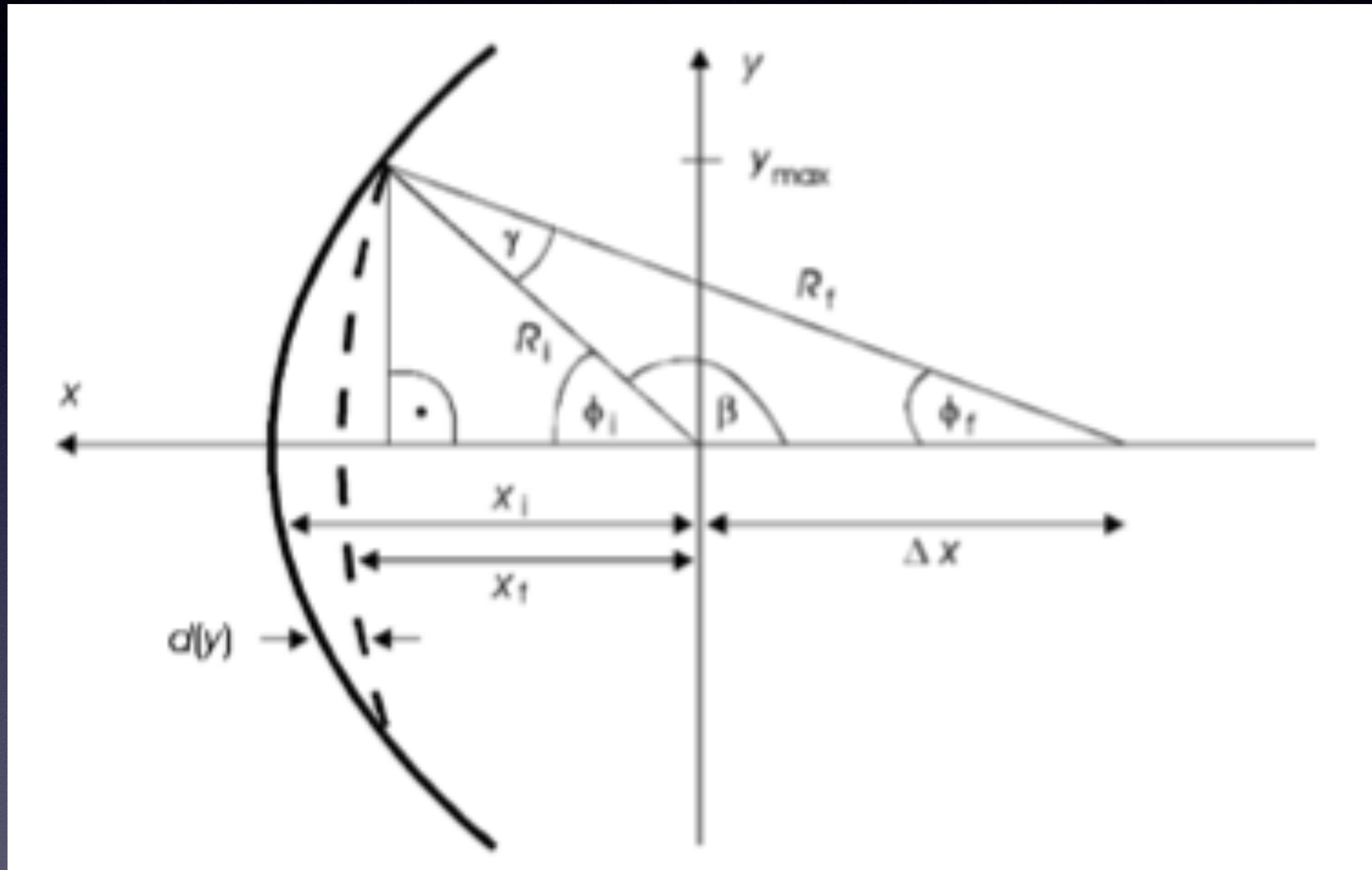
M. H. Niemz, *Laser-tissue interactions: fundamentals and applications*, Springer, Berlin (1996) [doi:10.1007/978-3-662-03193-3].

Soczewka oka



M. H. Niemz, *Laser-tissue interactions: fundamentals and applications*, Springer, Berlin (1996) [doi:10.1007/978-3-662-03193-3].

Rogówka oka photorefractive keratectomy (PRK)



Dermatologia a port wine stan



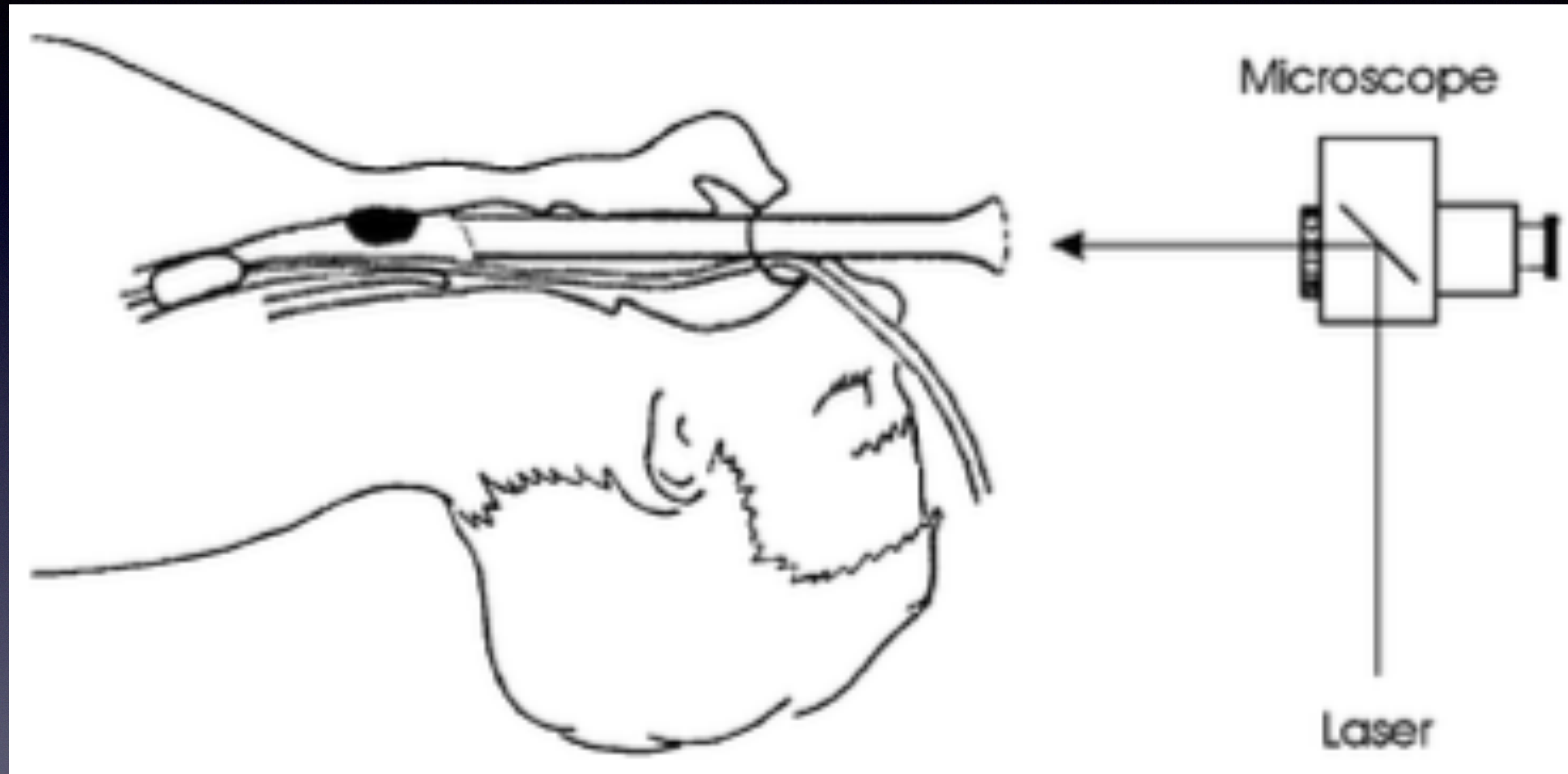
Fig. 4.62. (a) Preoperative state of a port wine stain. (b) Postoperative state of the same stain after several treatments with an argon ion laser (pulse duration: 0.3 s, power: 2.5 W, focal spot size: 2 mm). Photographs kindly provided by Dr. Seipp (Darmstadt)

Dermatologia usuwanie tatuaży



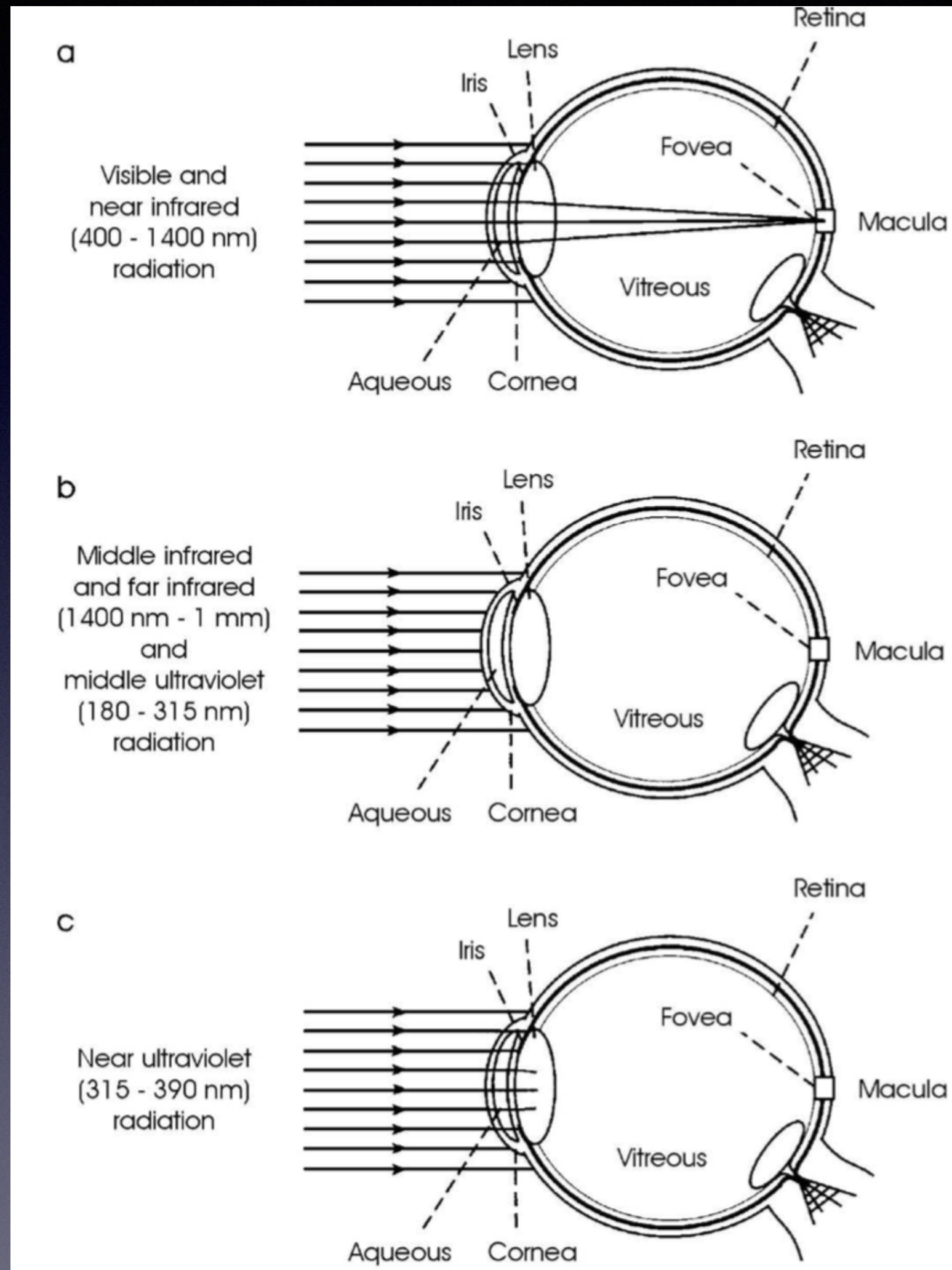
M. H. Niemz, *Laser-tissue interactions: fundamentals and applications*, Springer, Berlin (1996) [doi:10.1007/978-3-662-03193-3].

Laryngologia/Pulmunologia guzy tchawiczo-oskrzelowe



M. H. Niemz, *Laser-tissue interactions: fundamentals and applications*, Springer, Berlin (1996) [doi:10.1007/978-3-662-03193-3].

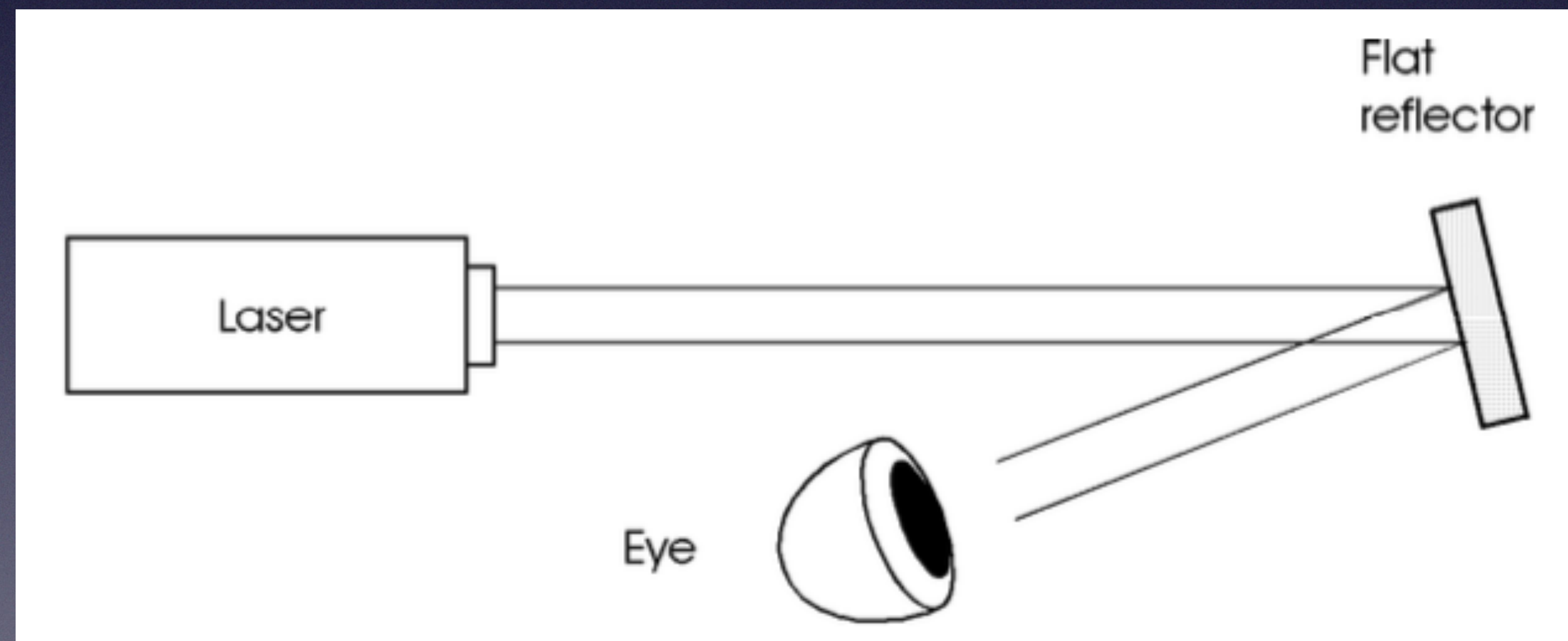
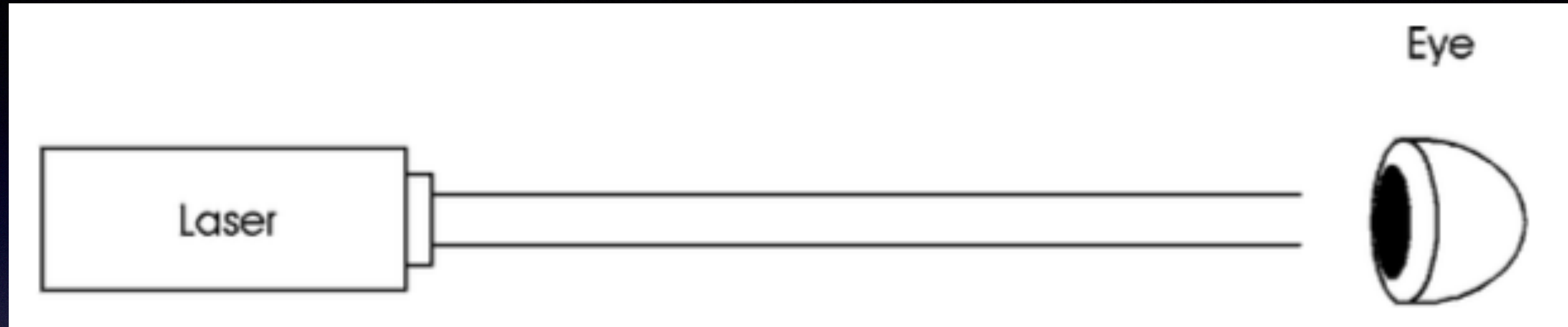
Laser safety



<https://spie.org/Images/Graphics/Newsroom/2019articles/Caution-920x450.jpg>

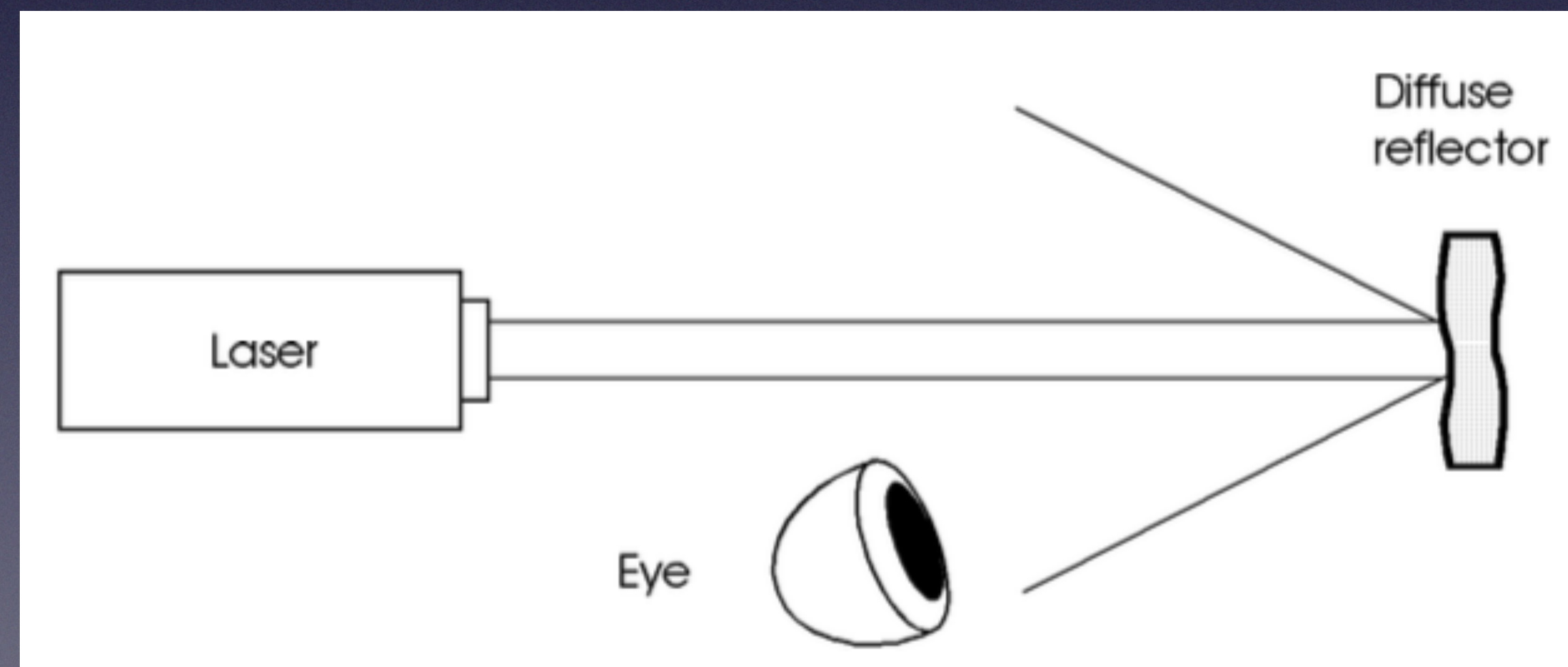
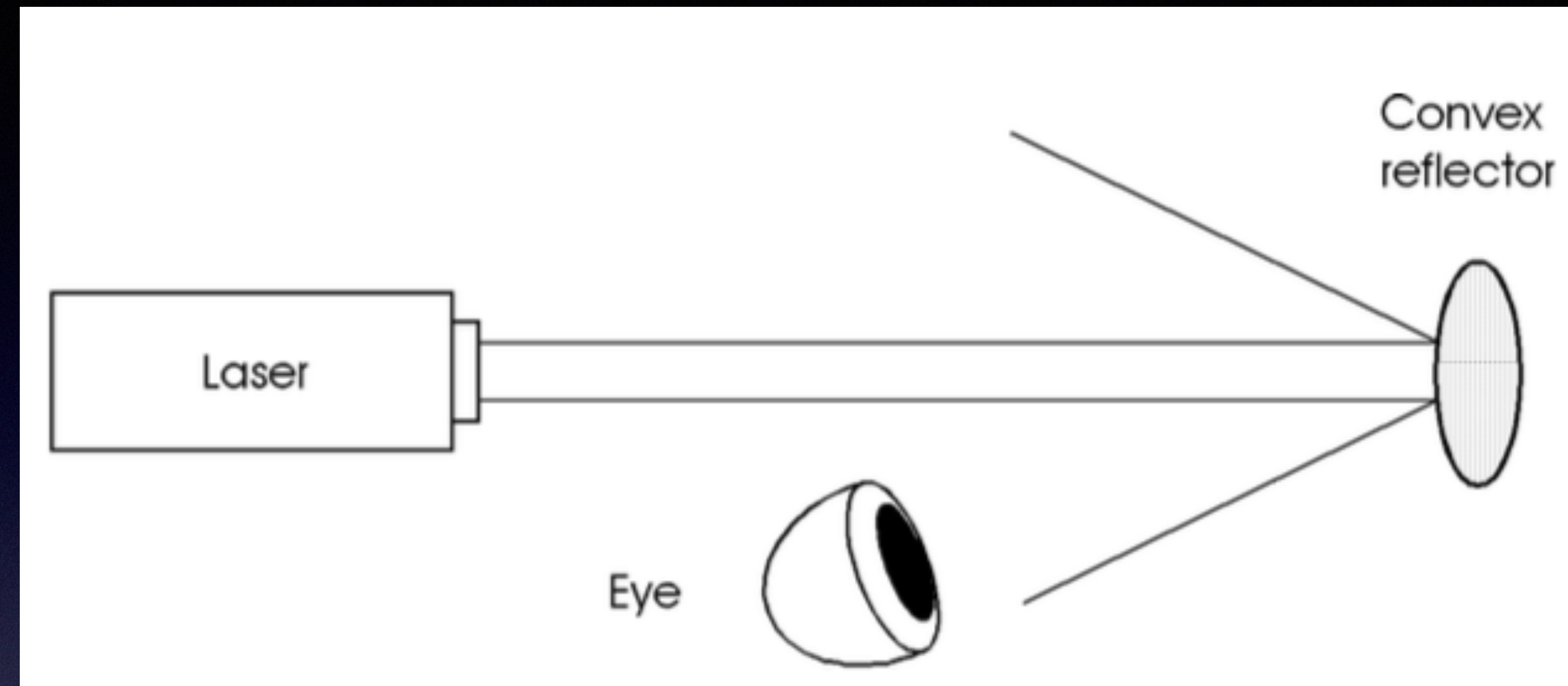
M. H. Niemz, *Laser-tissue interactions: fundamentals and applications*, Springer, Berlin (1996) [doi:10.1007/978-3-662-03193-3].

Laser safety



M. H. Niemz, *Laser-tissue interactions: fundamentals and applications*, Springer, Berlin (1996) [doi:10.1007/978-3-662-03193-3].

Laser safety



Dziękuję za uwagę !

W wykładzie wykorzystano materiały z podręcznika:

„Technika laserowa i jej zastosowanie”- R. Jóźwicki, Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa 2009 oraz z książki: B. Ziętek „Lasery”, Wydawnictwo UMK, Toruń 2005.

M. H. Niemz, *Laser-tissue interactions: fundamentals and applications*, Springer, Berlin (1996) [doi:10.1007/978-3-662-03193-3].