

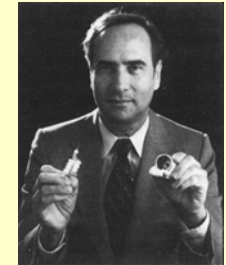
Laser

light **a**mplification by **s**timulated **e**mission of **r**adiation

Brief laser history

1917 - Albert Einstein: theoretical prediction of stimulated emission

1954 - N.G. Basow, A.M. Prochorow, C. Townes: ammonia maser*



1960 - Theodore Maiman: first laser
(ruby laser)

***M**icrowave **A**mplification by **S**timulated **E**mission of **R**adiation

Brief laser history



Alexander Prokhorov



Charles H. Townes



Nicolay Basov

Nobel prize in Physics 1964
for work in quantum electronics leading to lasers and masers



Denes Gabor

Nobel prize in Physics 1971
for invention of holography

Brief laser history



Steven Chu



William D. Phillips

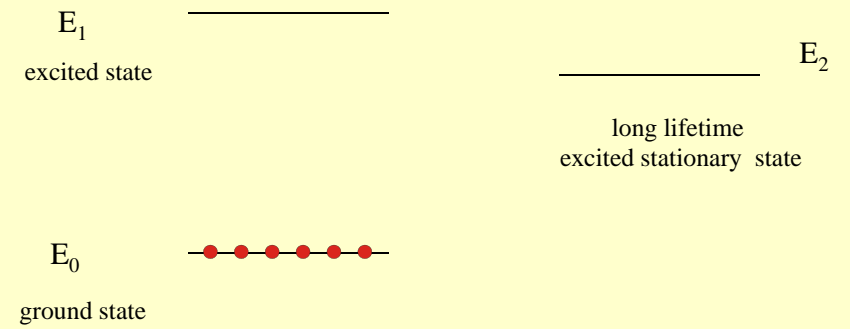


Claude Cohen-Tannoudji

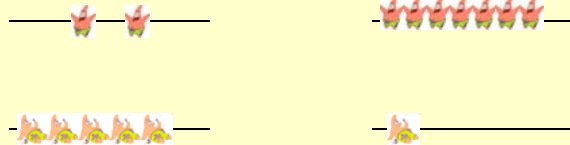
Nobel prize in Physics 1997
for development of methods to cool and trap atoms with laser light.

Fundamentals of Laser Operation

Special electronic energy states - precondition for laser action



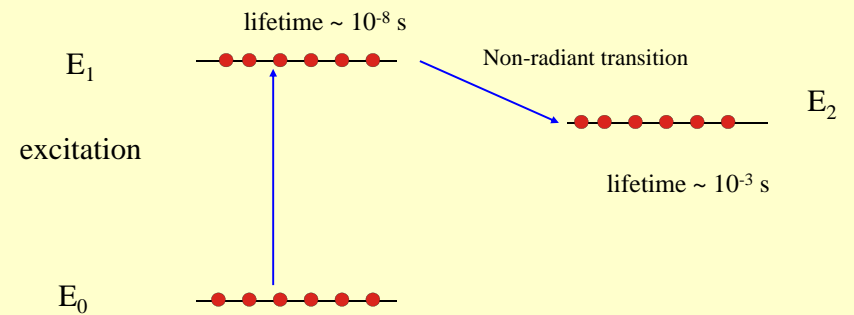
Occupancy in energy levels



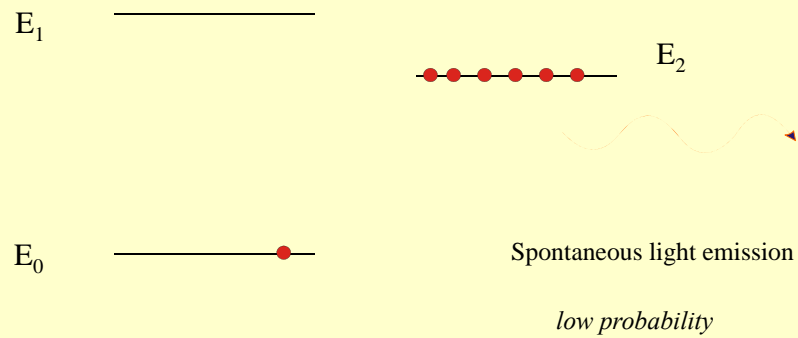
Thermal equilibrium

Population inversion

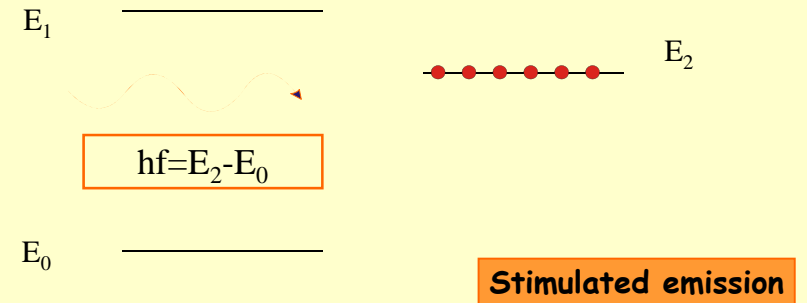
Elementary radiative processes:



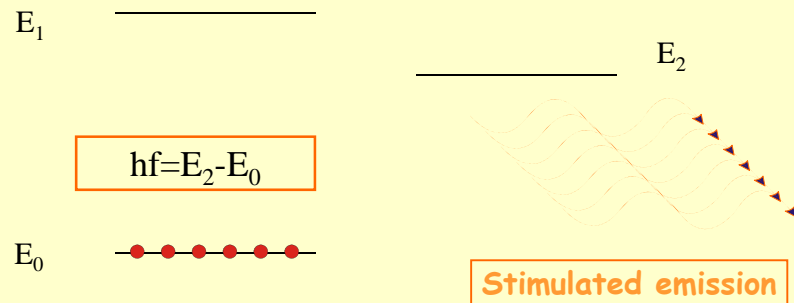
Spontaneous photon emission



Induction of atomic transition – relaxation of electrons in metastable state

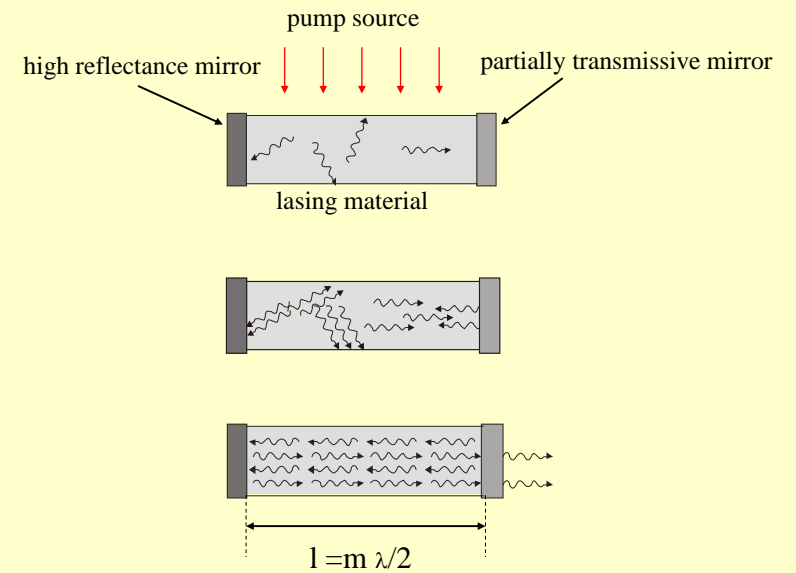


Induction of atomic transition – relaxation of electrons in metastable state



Phase,
polarisation,
direction and
frequency
of emitted and inducing photons are identical.

Operating a laser – optical resonator



Photons emitted by stimulated emission and inducing photons are identical

frequency
phase,
polarization
and direction.

Consequently laser light is

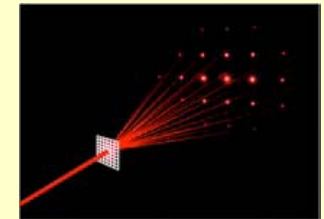
monochromatic
coherent
polarized
parallel, collimated beam

Light generated by stimulated emission

monochromatic – small spectral width

coherent – phase equivalency in space
and in time
ability for interference

polrized,
can provide large spatial density due to small divergence.



Possibility of very short pulses – ps , fs

Possibility of high power – kW - GW

Types of laser

Based on active medium:

solid state lasers – Crystals or glasses doped with metal ions;
Ruby, Nd-YAG, Ti-sapphire
Red - infrared spectral range; possibility of high power

gas lasers – He-Ne laser (10 He/Ne). CO2 laser: CO2-N2-He
mixture;

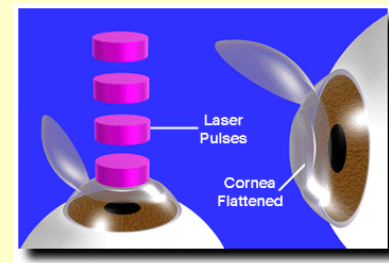
dye lasers – Dilute solution of organic dyes (e.g., rhodamine,
coumarine); pumped with another laser
Large power (in Q-switched mode); Tunable

semiconductor lasers – At the junction of p- and n-type, doped
semiconductors.
No need for resonator mirrors (internal reflection)

Excimer laser – excited dimer

Alapállapotban monomerek, gerjesztett állapotban
stabilis komplexek vagy dimerek

Pl. nemesgázok vagy
nemesgáz és halogén keverékek

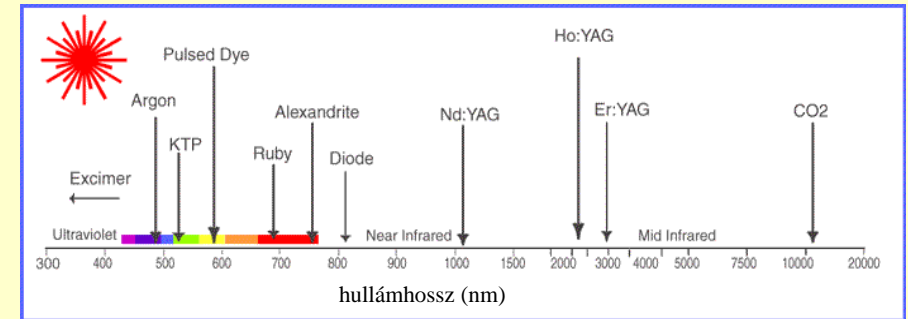


Ar ₂	126 nm
Kr ₂	146 nm
F ₂	157 nm
Xe ₂ [*]	172 & 175 nm
ArF	193 nm
KrF	248 nm
XeBr	282 nm
XeCl	308 nm
XeF	351 nm
CaF ₂	193 nm
KrCl	222 nm
Cl ₂	259 nm

Types of laser

Depending on power:

- 5 mW – CD-ROM drive
- 5–10 mW – DVD player or DVD-ROM drive
- 100 mW – High-speed CD-RW burner
- 250 mW – Consumer DVD-R burner
- 1–20 W – output of the majority of commercially available solid-state lasers used for micro machining
- 30–100 W – typical sealed CO₂ surgical lasers
- 100–3000 W (peak output 1.5 kW) – typical sealed CO₂ lasers used in industrial laser cutting



Application of lasers

Criteria for selection

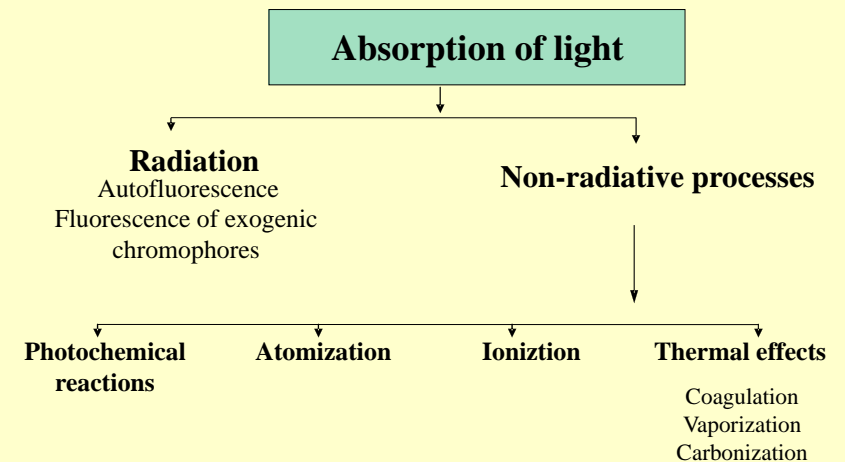
- wavelength
- power
- continuous/pulse mode

Fields of application

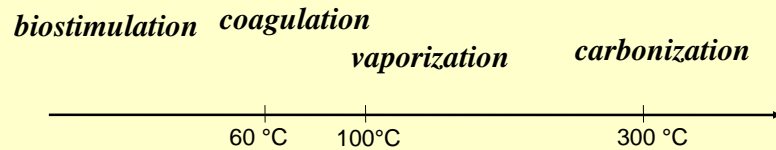
- Medicine** (health and beauty) – diagnostic and therapy
- Industry:** Cutting, welding, material heat treatment, marking parts
- Defense:** Marking targets, guiding munitions, missile defence, electrooptical countermeasures (EOCM), alternative to radar
- Research:** spectroscopy, laser ablation, Laser annealing, laser scattering, laser interferometry, LIDAR, Laser capture microdissection
- Product development/commercial:** laser printers, CDs, barcode scanners, thermometers, laser pointers, holograms.
- Laser lighting displays:** Laser light shows

Biomedical applications of laser

Light induced processes in tissues



Thermal effects



Light induced processes in tissues

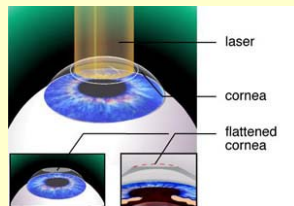
Selectivity of processes: getting the right amount of the right wavelength of laser energy to the right tissue to damage or destroy only that tissue, and nothing else.

Photoablation – volatilization of tissue by UV radiation

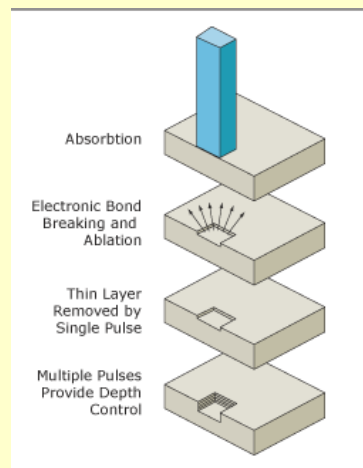
Mechanism: atomization/vaporization

UV laser pulse (10 MW/cm^2 - 10 GW/cm^2)

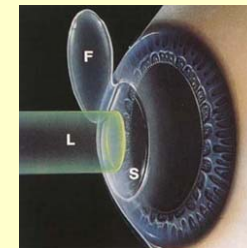
Excimer laser (193 nm-351 nm), 10-20 ns pulse



Photorefractive Keratectomy (PRK):
myopic eye is too big compared to the refraction of its lens



Corneal reshaping: LASIK (Laser in situ Keratomileusis)



The epithelium is surgically peeled back and the underlying stroma is ablated. LASIK allows correction of even severe myopia because it is not limited by the finite thickness of the epithelium.

Photodisruption

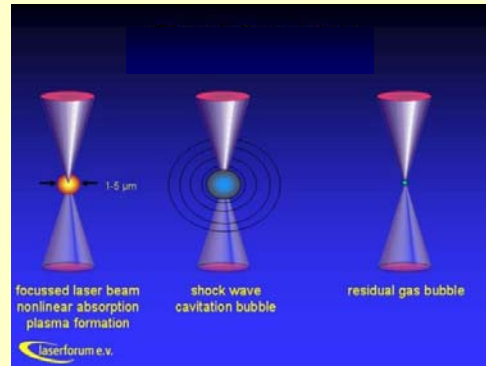
Focused, high intensity ns pulses

Kavitation

Water evaporation and CO₂
generation in the cavity

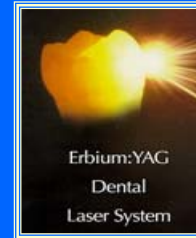
Shock wave

Distruction of surrounding
tissues



Applications in dentistry:

Er:YAG laser
2940 nm



Absorption in water and
hydroxyapatite

Vaporization and mechanical
shockwave

caries removal



caries removal



caries removal





Argon laser
488, 514 nm



A rubber dam is put over your
teeth to protect the gums

Teeth whitening

Nd: YAP* laser

930, 1080,
1340 nm



frenectomy



gingivectomy

*YAlO₃:Nd

Dermatological applications:

„resurfacing” – ablation technic for renewal of epidermis



wrinkles,
damages,
acnes ...



Er:YAG laser (2940 nm) or CO₂ laser (10600 nm)

Nd:YAG laser

1064 nm

Removal of superficial blood vessels, veins



Photocoagulation based correction of veins



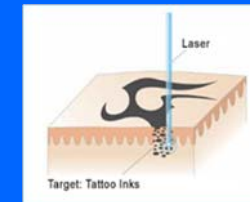
Hair removal



Tattoo removal

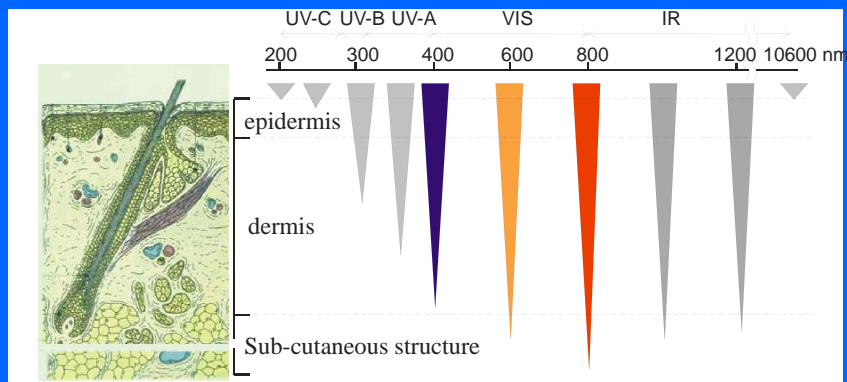


before after



ruby laser (694 nm) is specifically absorbed by the color pigments in the tattoo

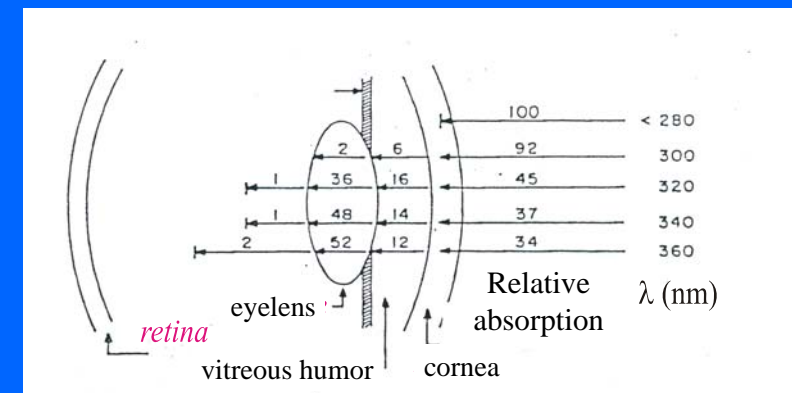
Penetration of light into the skin



Light intensity is attenuated due to absorption, reflection, refraction.

Penetration depth depends on the wavelength.

Penetration of light into the skin



Photodynamic therapy (PDT)

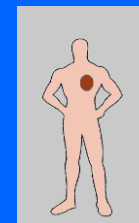
Combined application of light and photosensitizer
in oxygen rich environment.

T. Dougherty: Activated dyes as antitumor agents.
J. Natl. Cancer. Inst. 1974

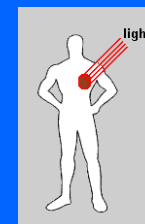
Steps of the treatment



Administration
of
photosensitizing
agent (PS)

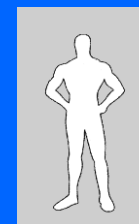


Accumulation of PS
in tumour

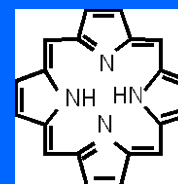
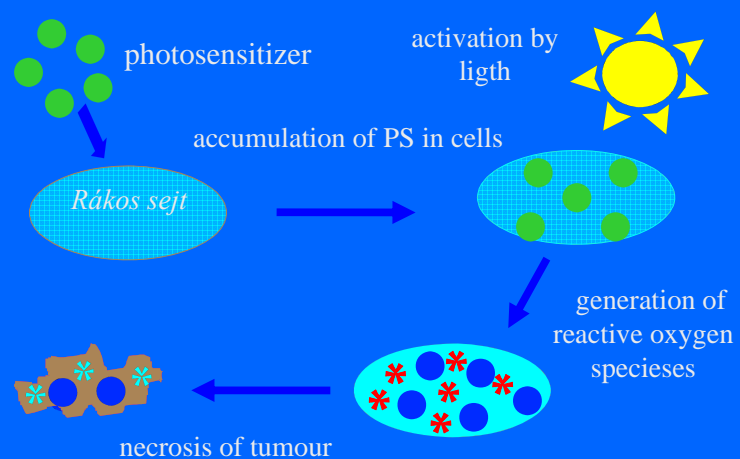


Exposure

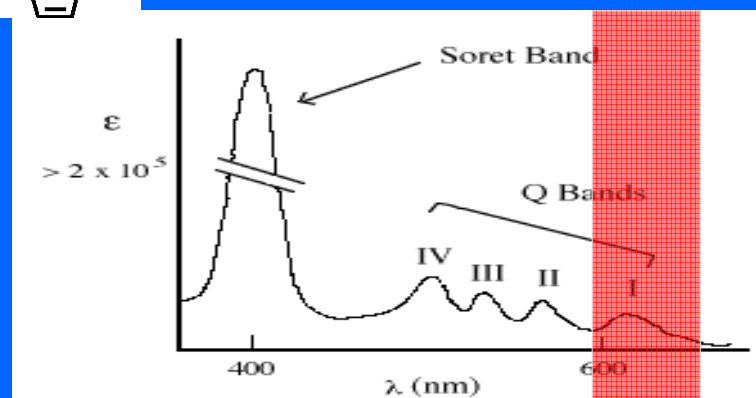
Selective tumour
destruction



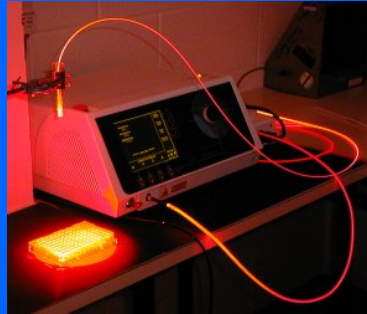
Mechanism of action



Typical absorption of porphyrins



Selection of light source



Monochromatic – red

high intensity

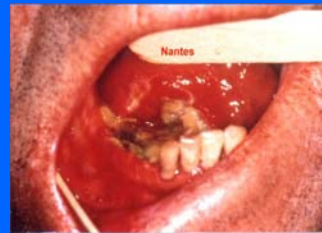


laser

Application fields of PDT

- *destruction of malignant tissues*
- *removal of non-malignant structures*
- *inactivation of microorganisms*
 - in dentistry
 - dermatology
 - sterilization of blood products
 - sterilization of water reserves

Squamous cell carcinoma (SCC)



24 heures after treatment



7 days after treatment



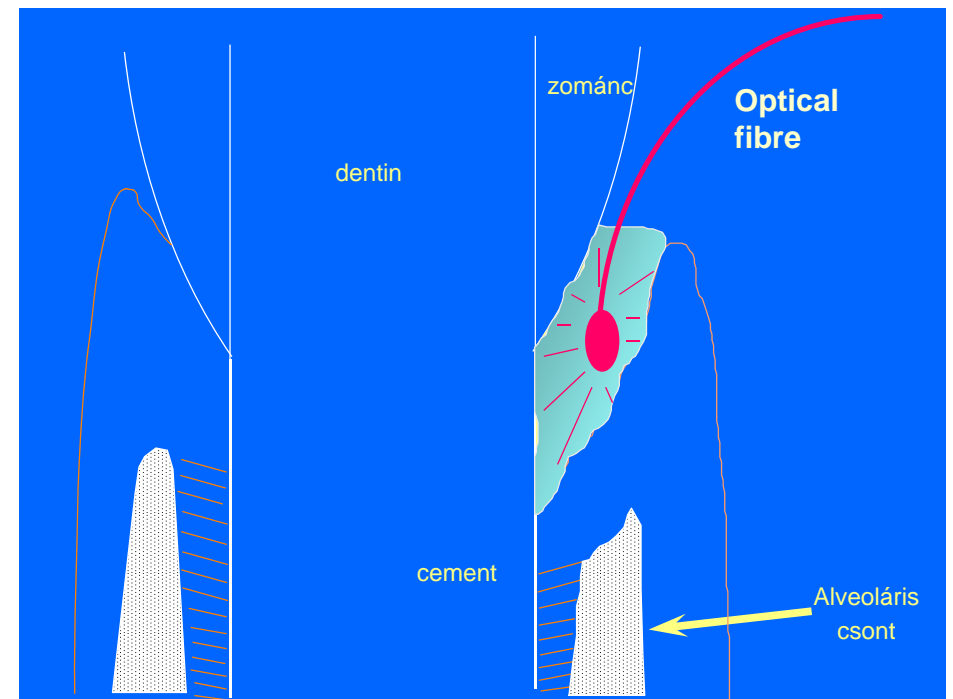
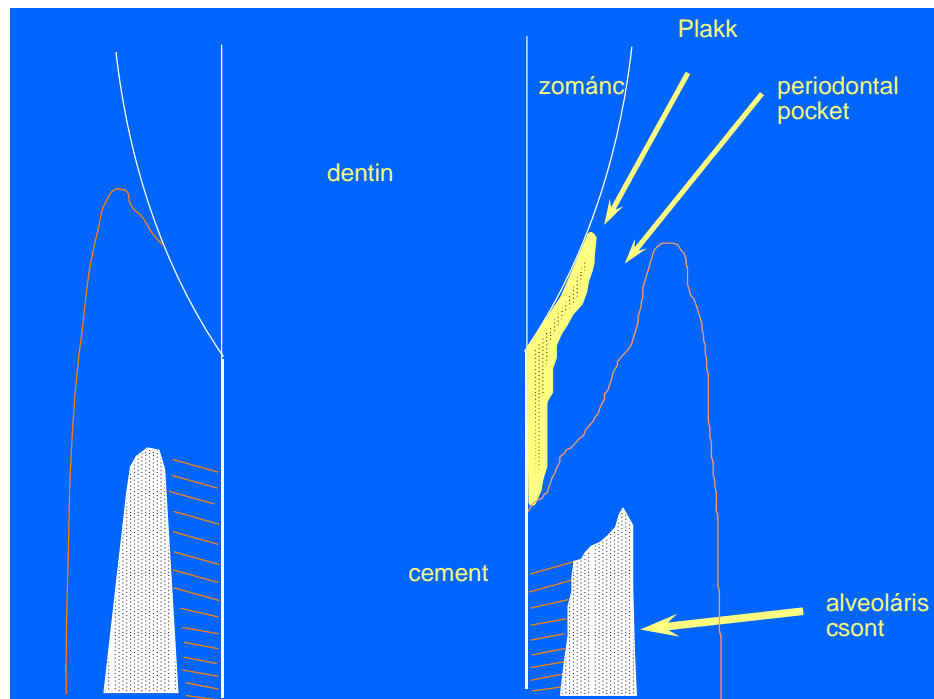
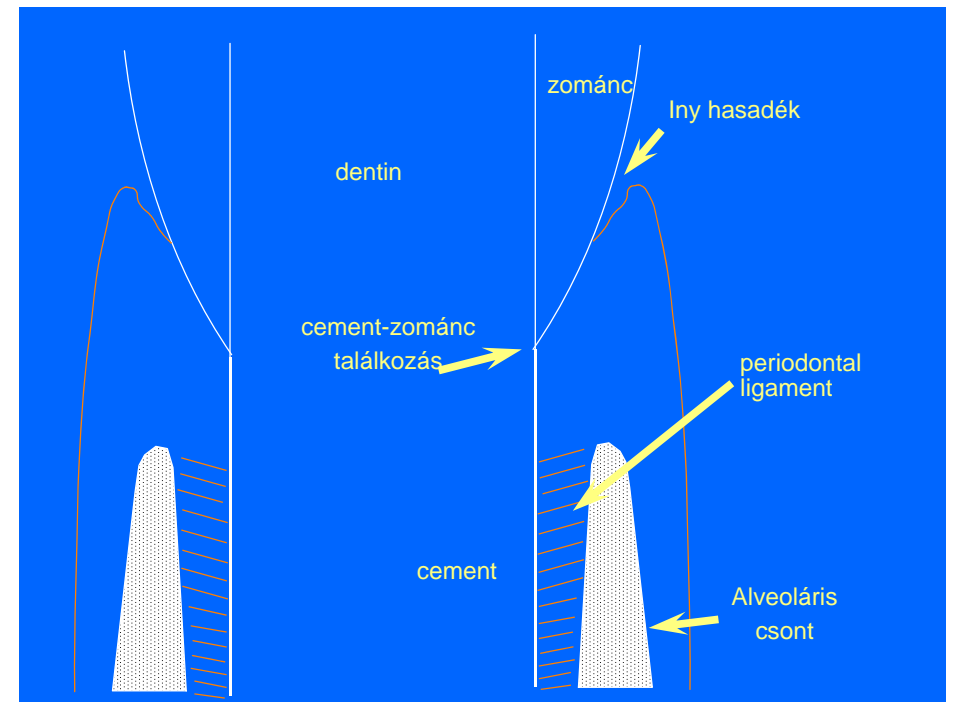
4 months after treatment

fogágygyulladás kezelése application of photosensitizer

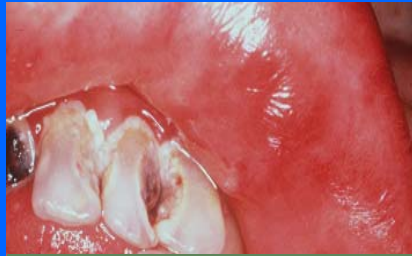


fogágygyulladás kezelése #2

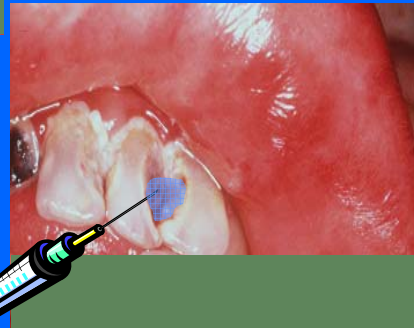
Irradiation of sub... region



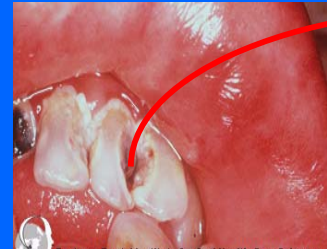
Treatment of caries #1



application of photosensitizer



Treatment of caries #2



Irradiation



Restoration of treated region

Damjanovich, Fidy, Szöllősi: Medical Biophysics

II. 2.2

2.2.5

2.2.7

2.2.8

IX. 1.1

IX. 1.2