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WINTER COLLEGE ON

ATOMIC AND MOLECULAR PHYSICS

(9 March - 3 April 1987)

LASERS IN MEDICINE

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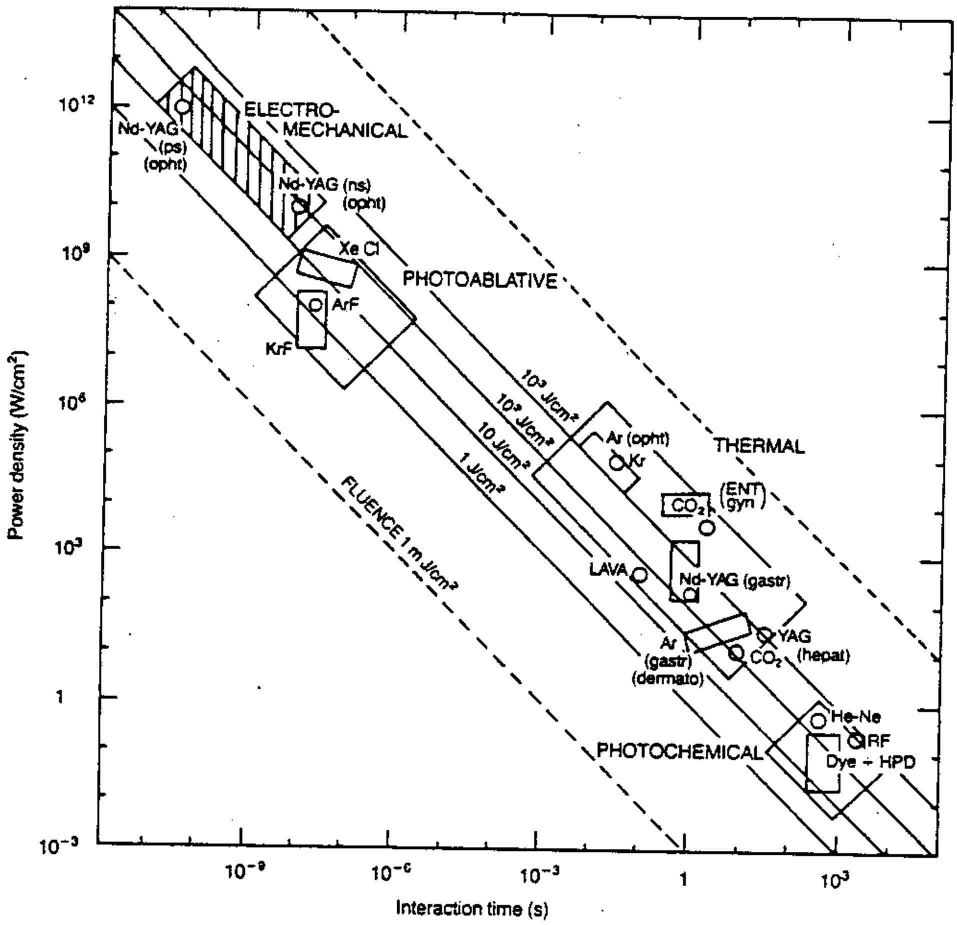


Fig. 1. Medical laser interaction map. The ordinate shows the irradiance (in W/cm², on a logarithmic scale), and is commonly labelled the power density. The abscissa shows the interaction time. The diagonals show several lines of constant fluence (in J/cm²). The boxed areas, labelled electromechanical, photoablative, thermal and photochemical (see text) enclose points that correspond to more than 50 experimentally determined optimal variables obtained from most published reports of clinical and experimental applications of lasers in medicine.
Nd-YAG, neodymium-doped yttrium aluminium garnet laser; XeCl, xenon chloride laser, ArF, argon fluoride laser; KrF, krypton fluoride laser; Ar, argon laser; Kr, krypton laser; CO_2, carbon dioxide laser; Lava, laser-assisted vascular anastomosis; He-Ne, helium-neon laser; HPD, haematoporphyrin derivative. RF, radio frequency; ps, picosecond; ns, nanosecond; opht, ophthalmology; ENT, otorhinolaryngology; gyn, gynaecology; gastr, gastrology; dermato, dermatology; hepat, hepatology.

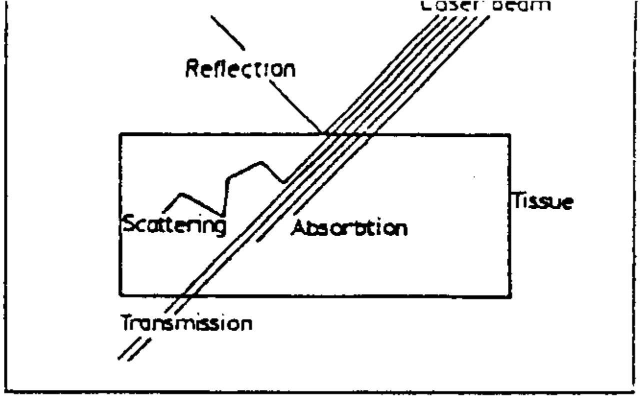
Source: Photophysical Processes in Recent Medical Laser Developments
by Jean-Luc Boulnois
Lasers in Medical Science 1 (1986) 47-66

Table 2: Selected Medical Laser Thermal Applications

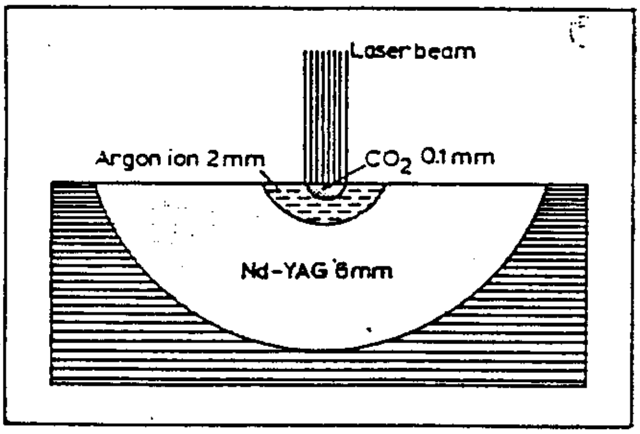
Specialty	Application	Laser
Ophthalmology	Retinal photocoagulation	Argon, Krypton
	Trabeculoplasty	Argon
Gynecology	Ablation of cervical lesions	CO_2
Gastroenterology	Hemostasis of bleeding ulcers	Nd:YAG
Otolaryngology	Ablation of airway obstructions	Nd:YAG
	Ablation of polyps and tumors	CO_2
Dermatology	Photocoagulation of portwine stains, teleangiactasia	Argon
	Ablation of warts, tattoos, and neoplasia	CO_2
Neurosurgery	Ablation of neural tumors	CO_2

from: Lasers & Applications
November 1986 p. 62

Laser - Tissue Interaction
by Roy C. McCord



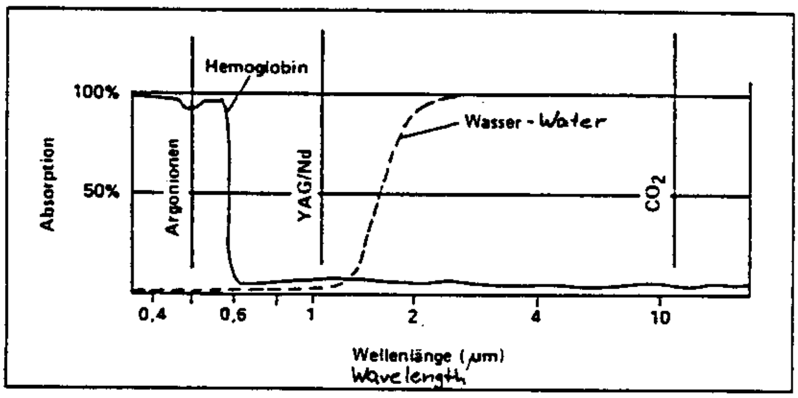
The fate of laser light in tissue



Different types of lasers penetrate tissue to varying degrees

from: How lasers turn tumors to vapour
New Scientist 20 February 1986 p. 4

Wavelength-dependent absorption of water and hemoglobin cf to different laser emission lines



from: Der Laser in der Medizin
by G. J. Müller et al.
Umschau 1986/4
p. 233-240

Penetration depth of radiation into skin

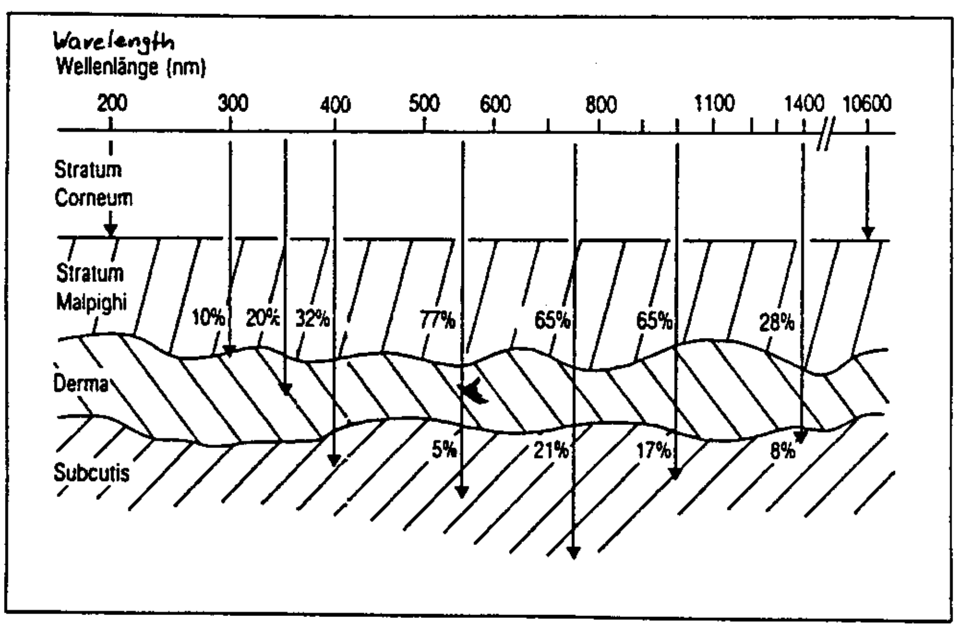


Table 1: Selected Absorption Coefficients of Biological Tissues

Tissue	Wavelength (nm)	α (cm^{-1})
Blood, oxygenated[1] (normal hematocrit)	620	6.2
	805	6.2
Blood, reduced[1] (normal hematocrit)	620	18.2
	805	6.2
Epidermis, white[2]	400	2.8
	500	1.2
	600	0.3
Fat, subcutaneous	400	0.7
	500	0.4
	600	0.2
Liver (rat)[3]	1064	15.2
Kidney (rat)[3]	1064	15.5
Retinal Pigment	514	1587
Epithelium[15]	633	821
	1060	120

from: Lasers & Applications Nov. 1986 p.61

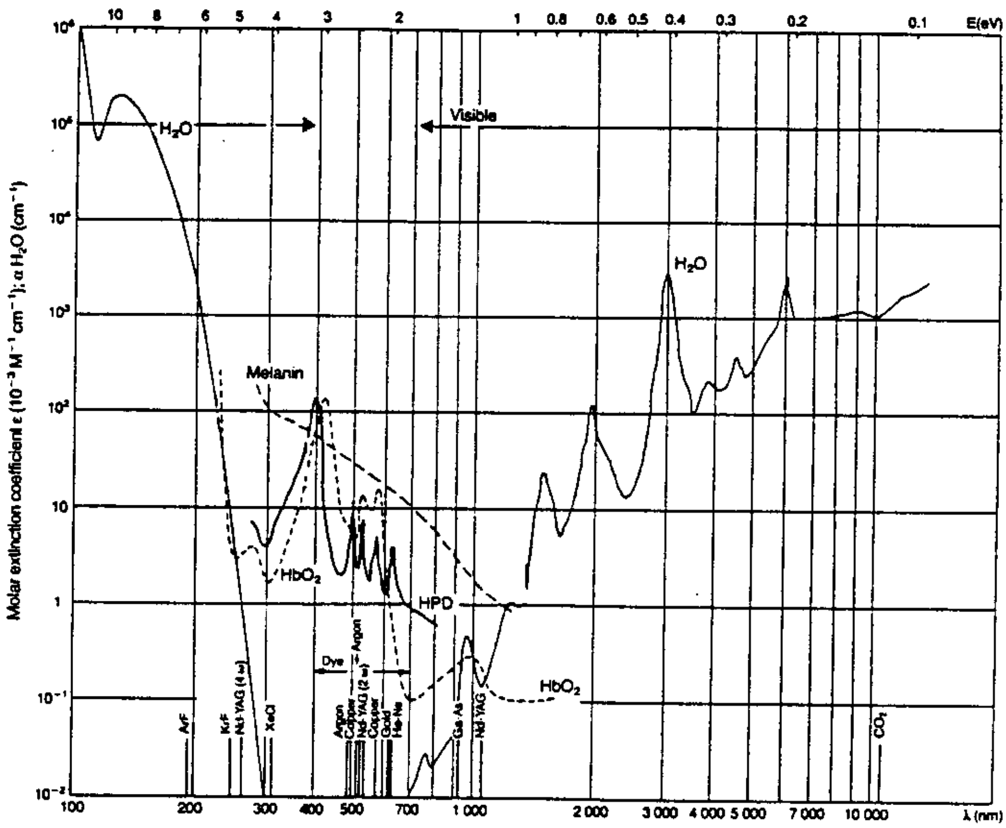


Fig. 2. Absorption coefficient spectrum of water, haemoglobin (HbO_2), melanin and haematoporphyrin derivative (HPD), together with the wavelength positions of the most widely used medical lasers.

from: Lasers in Medical Science 1 (1986) 47-66

Effects of Excimer Radiation on cells

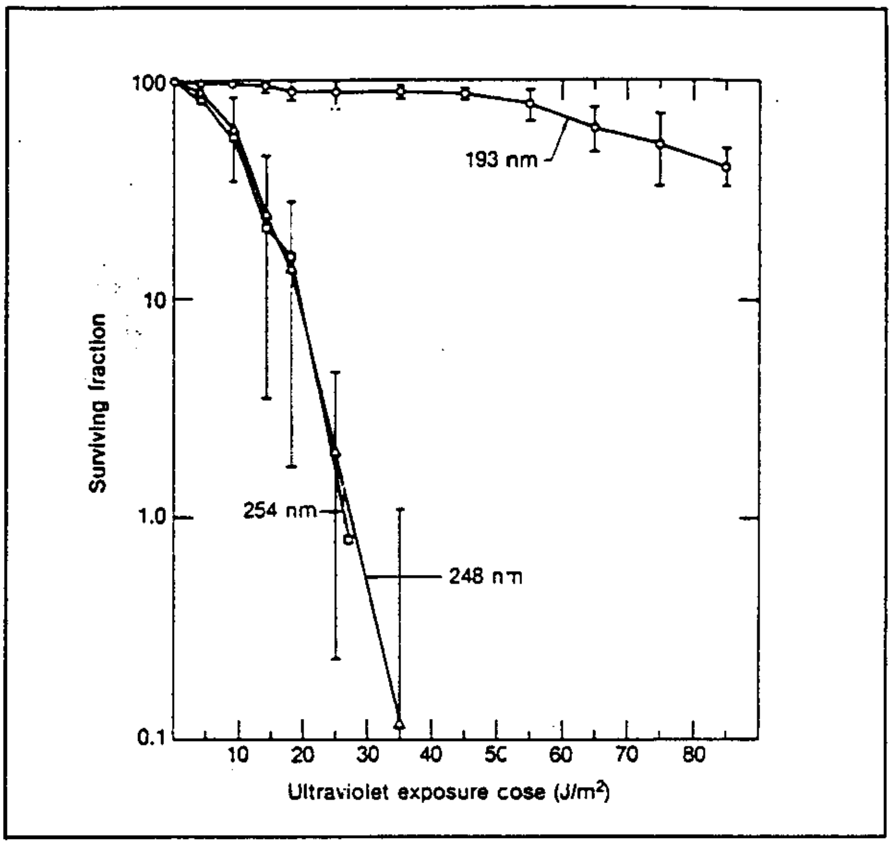


Figure 4. Cytotoxicity of excimer laser radiation compared to germicidal lamp radiation (254 nm: 5.3 × 10^{-5} W/cm²; 248 nm: 3.5 × 10^{2} W/cm²; 193 nm: 5.4 × 10^{2} W/cm²).

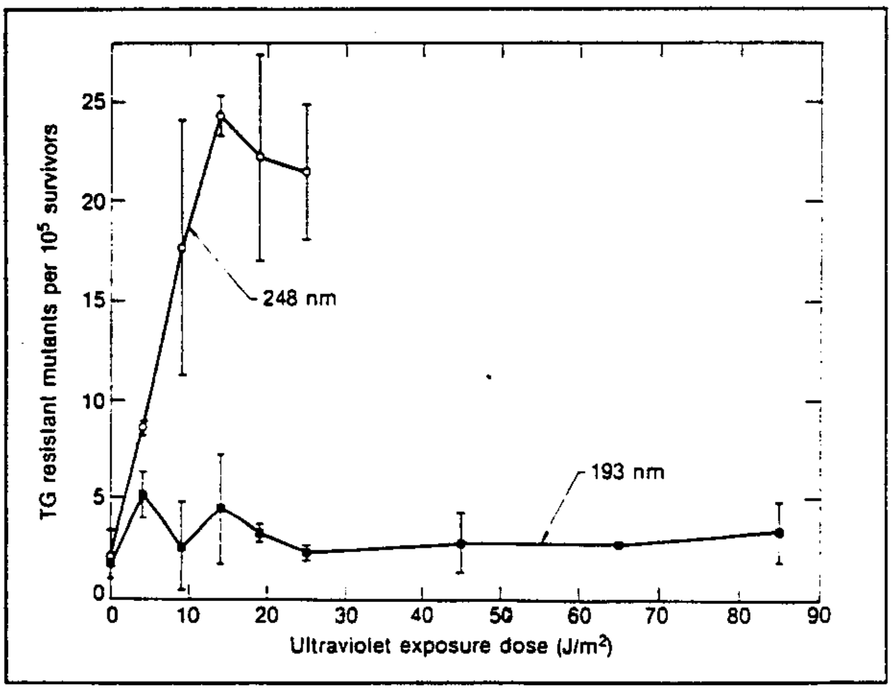


Figure 5. Mutagenicity studies of excimer laser radiation.

both pictures from: Excimer Lasers in Medicine
by David Muller
Lasers & Applications May 1986 p. 87

Laser-induced temperature increase and its influence on tissue damage

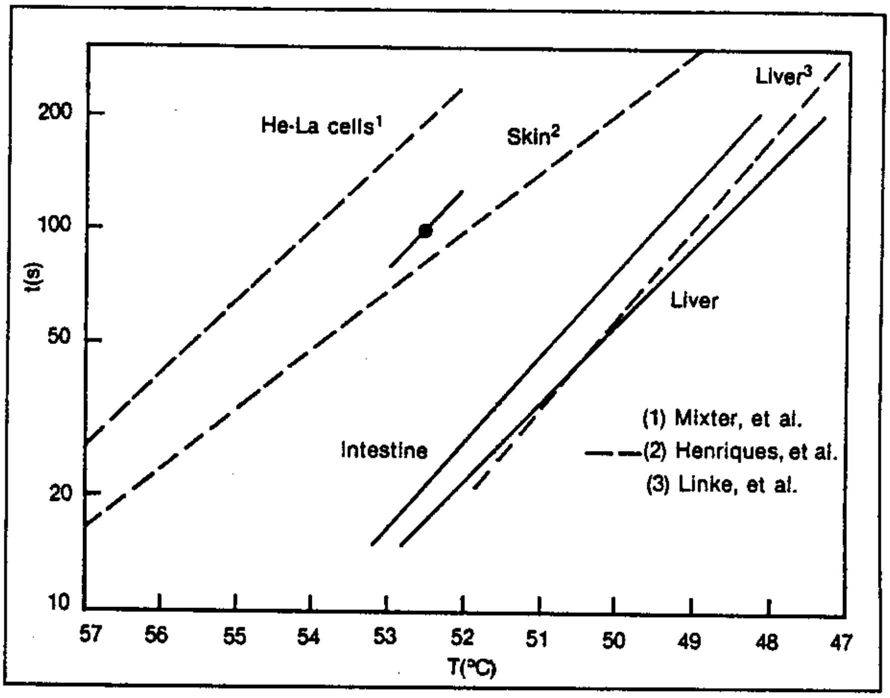


Figure 3a. Plots ln t vs 1/T (inverted abcissa) for different tissue and cell types. The graph relates the viability of cells to stepped temperature increases of various durations.

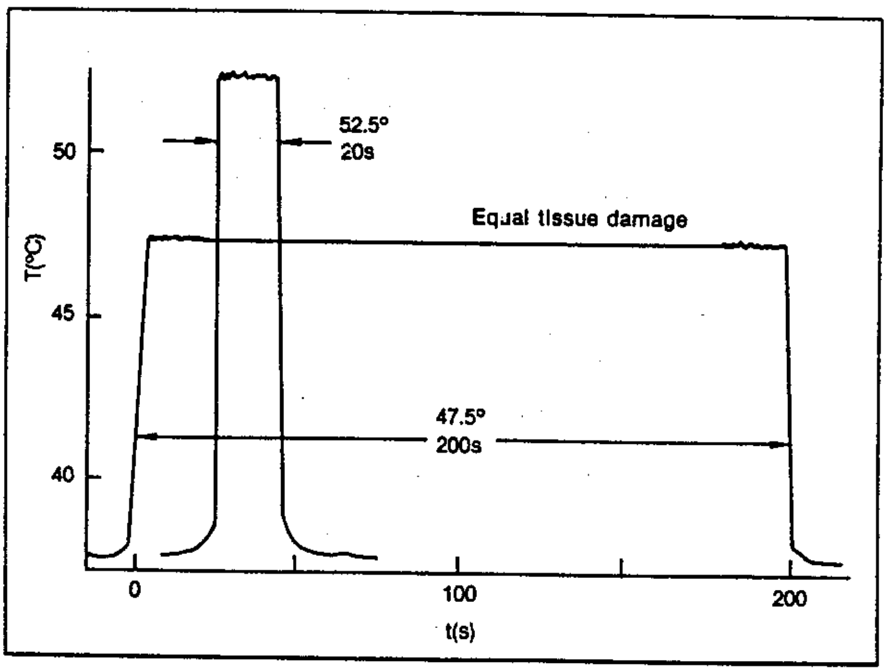


Figure 3b. Dramatizes the effect small temperature changes have on cell viability. Necrosis (death of 50 percent of cell population) occurs ten times faster with a 5°C increase.

from: Lasers & Applications November 1986 p. 63

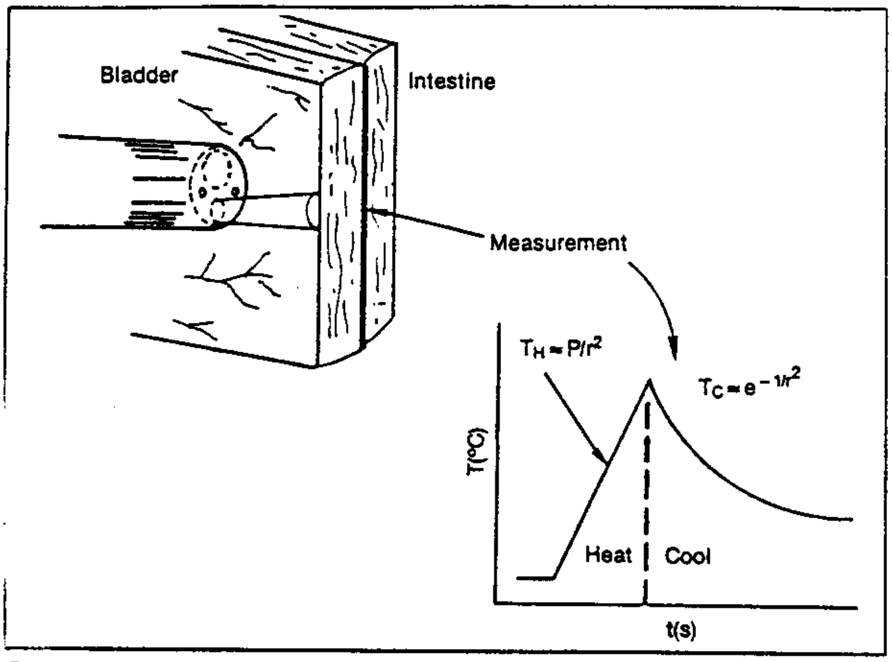


Figure 4a. Shows a plot of the temperature on the outside of a bladder wall after it is irradiated interiorly with 20-W, Nd:YAG laser pulses of 1-second duration.

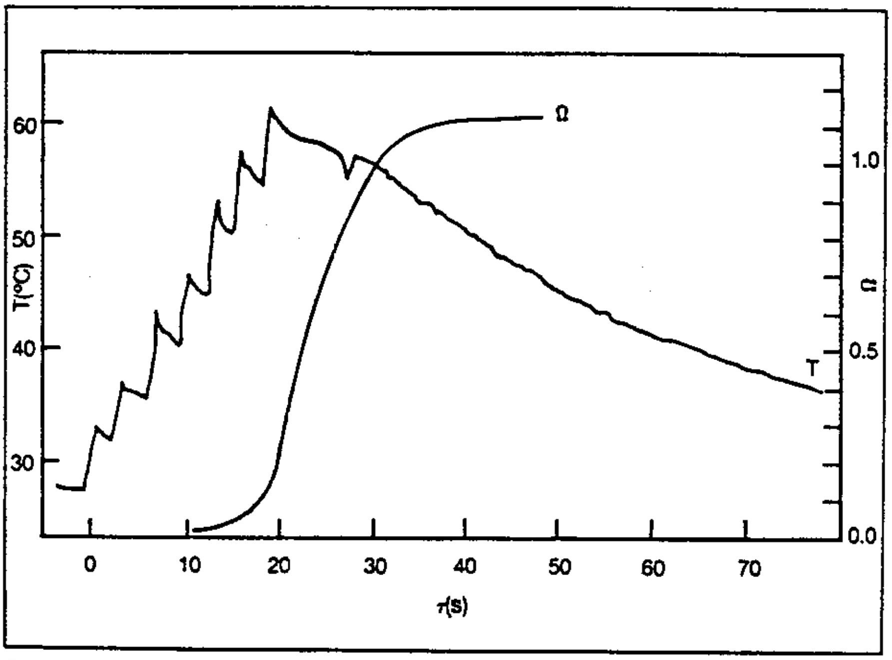


Figure 4b. The left ordinate plots the temperature increase of the bladder's exterior wall after a series of Nd:YAG pulses. The calculated damage integral is plotted on the right ordinate.

from: Lasers & Applications Nov 1986 p 64

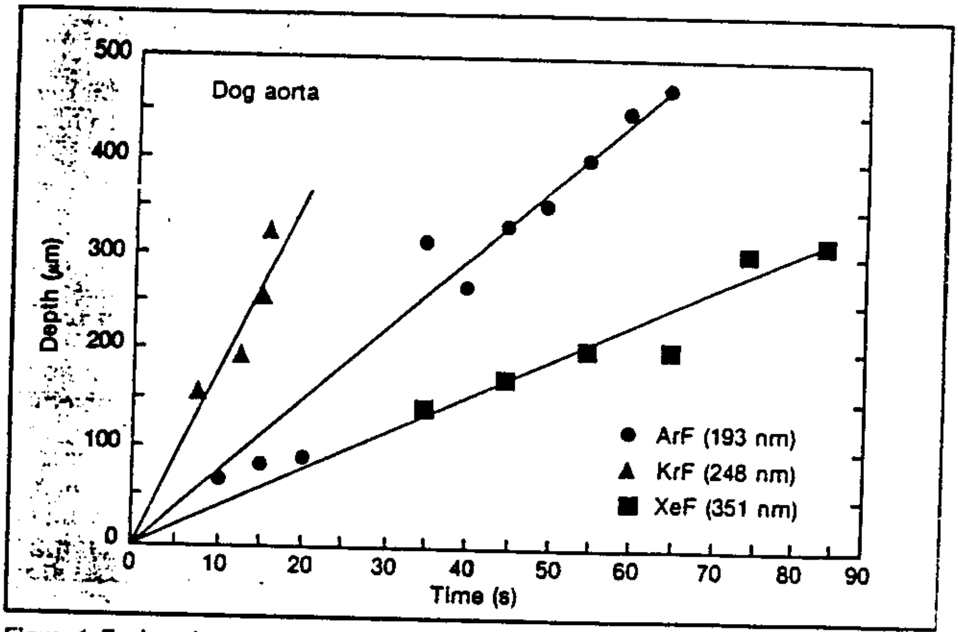
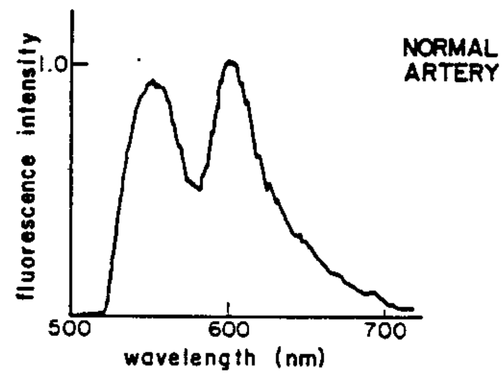
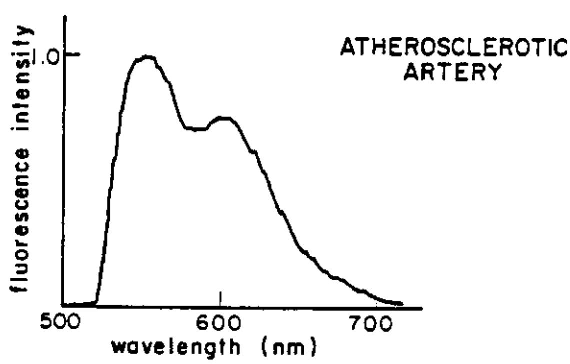


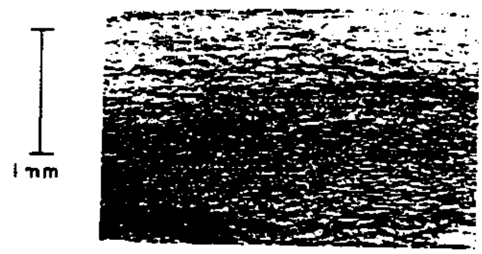
Figure 1. Excimer laser penetration depth as a function of irradiation time for a constant power density of 0.375 W/mm^2.

from: Lasers & Applications May 1986 p 85

Diagnosis of fibrous arterial atherosclerosis using fluorescence
by C. Kittrell







Source:
p. 2280 APPLIED OPTICS / Vol. 24, No. 15 / 1 August 1985

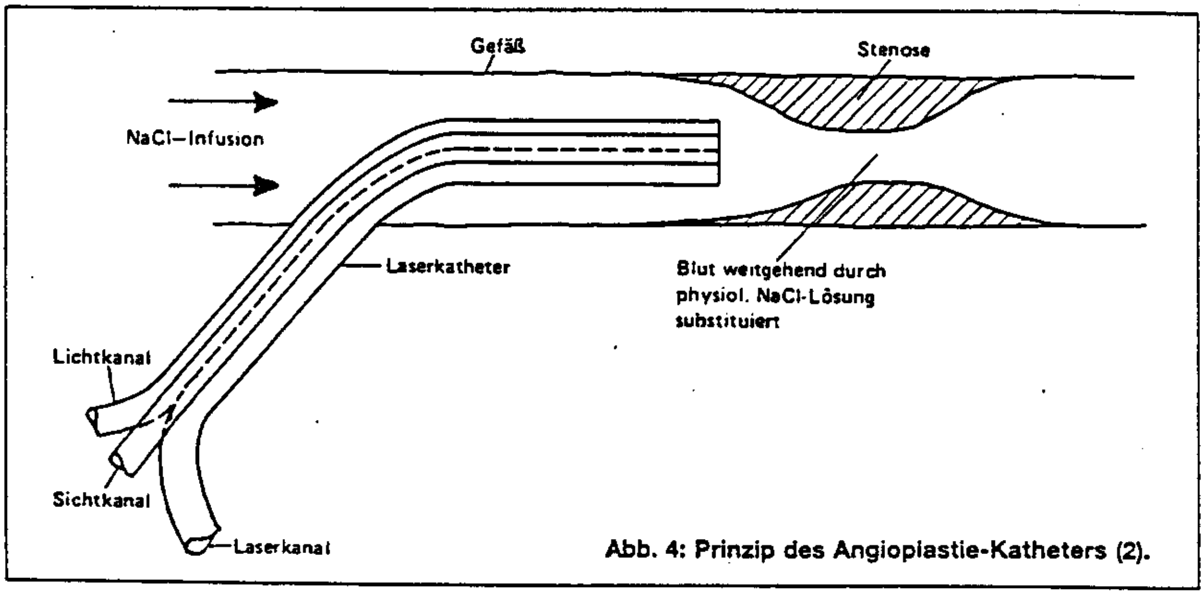
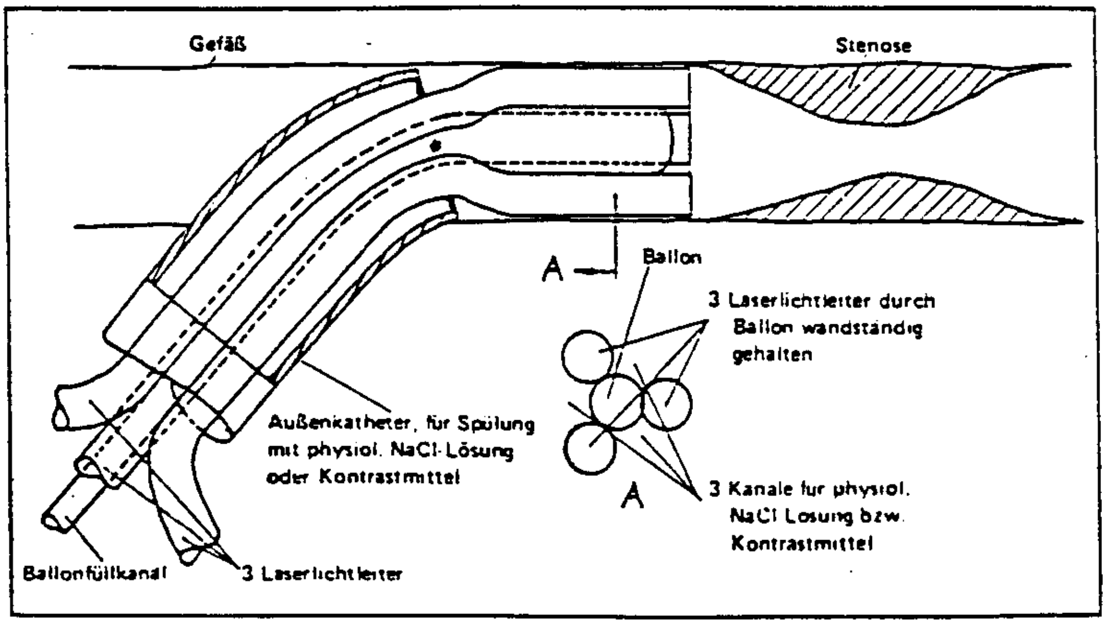


Abb. 4: Prinzip des Angioplastie-Katheters (2).

Catheters for Angiosurgery



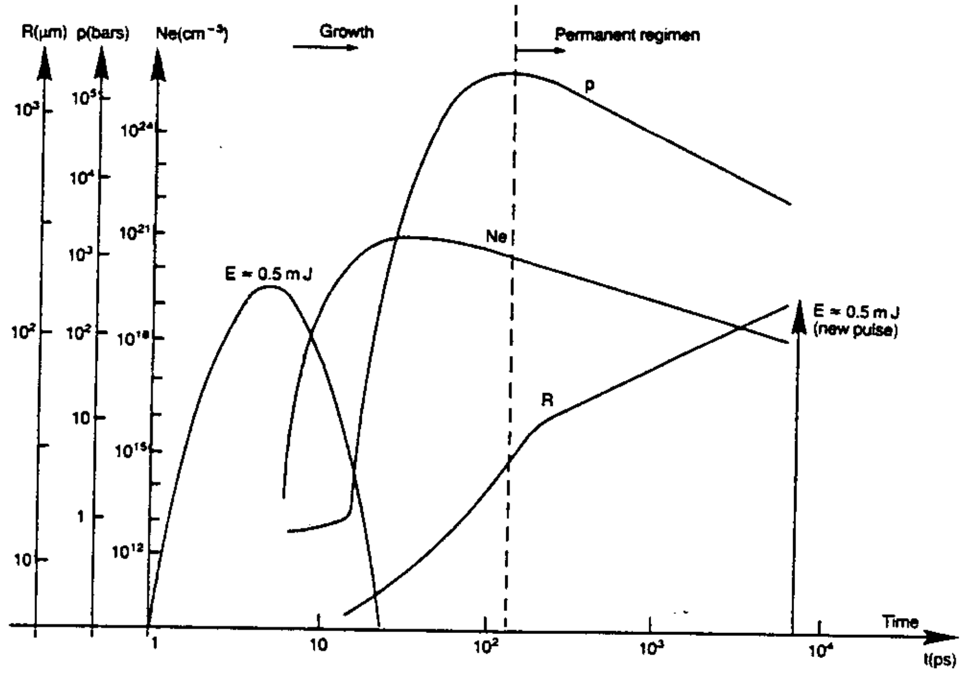


Fig. 5. Temporal evolution of plasma parameters (electron number density N_e, plasma radius R, and pressure p), following a laser-induced breakdown with 0.5 mJ energy in a 25 ps pulse (J.L. Boulnois, unpublished observations).

from: Lasers in Medical Science 1 (1986) 47–66

Source:

NATURE VOL. 316 25 JULY 1985 p. 327 : Laser biology and medicine by V.S. Letokhov

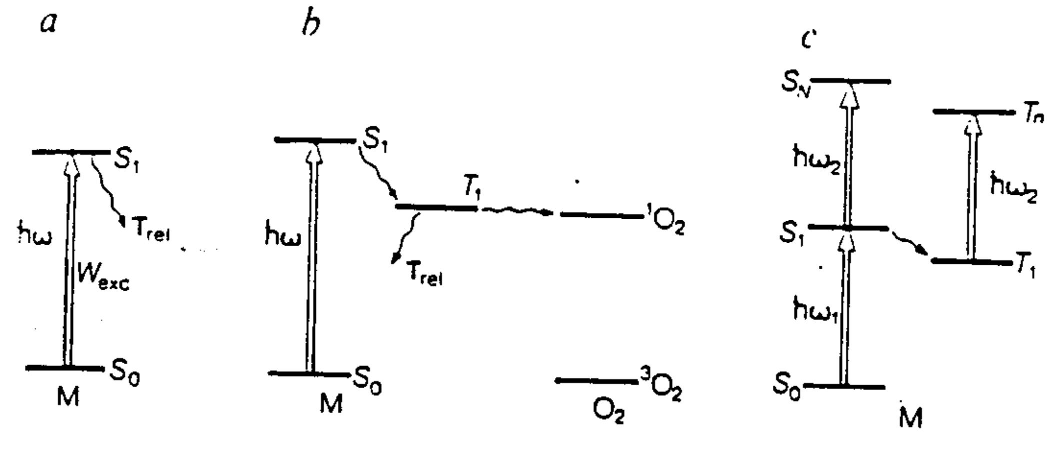


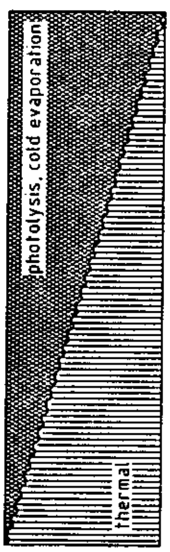
Fig. 3 Methods of photochemical modifications of biomolecules. *a*, One-photon excitation and subsequent photochemical reaction (phototherapy of neonatal jaundice by means of photodecomposition of bilirubin). *b*, One-photon excitation of sensitizer molecule, M, and transfer of excitation to modifiable molecule or molecules participating in modification photodynamical effect (tumour phototherapy; the oxygen-acceptor of excitation participates in oxidation). *c*, Two-photon excitation of highly lying triplet, T_1, or singlet, S_1, states and following photomodification or transfer of excitation to other molecules (nucleic acids in water).

Table 2. Medically useful interactions of light and matter.

Power density	Type of interaction	Mechanism	Application
mW/cm^2	Biostimulation [139]	Influencing certain parts of metabolism	Healing of inflammations and wounds
kW/cm^2	Coagulation	Denaturation and resulting clotting of proteins, etc., at local temperatures of 40-80°C	"Glueing" of tissue parts; clotting of bleeding
MW/cm^2	Evaporation	Water evaporates (partly explosively) from the tissue; breakdown of tissue structure	Cutting of tissues analogous to the surgical knife but contact-free.
GW/cm^2	Photoablation Photodisruption	Individual bonds are broken	Cold evaporation of tissue parts
TW/cm^2	Formation of microplasms	Molecules are ionized so that electron avalanches occur	Destruction of "hard" materials such as gallstones

Source: *Angew. Chem. Int. Ed. Engl. 26 (1987) 38-58*

Table 3. Possibilities for application of material processing in medicine

Laser type	Working wavelength [nm]	Presumed nature of interaction with tissue	Penetration depth into the skin	Main use following interaction [a]					Areas of medical application [b]					
				A	B	C	D	E	U	V	W	X	Y	Z
ArF excimer	193		Surface				×	×	×					
KrF excimer	248		Very small			(×)	×	×	×					
XeCl excimer	308		Small			×	×	×	×					
Kr$^{\oplus}$ ion	407		Deep	×	×	×				×				
Ar$^{\oplus}$ ion	516		Very deep	×	×	×				×	×	×	×	
Nd-YAG, frequency-doubled	532		Very deep		×	×	(×)			×				
He-Ne	620		Very deep	×						×				×
Semiconductor	780-1200		Deep	×										×
Nd-YAG	1064		Deep		×				×		×	×	×	
Er-YAG	2936		Small										×	
CO_2	10000		Small			×			×		×	×		

[a] A = biostimulation; B = coagulation; C = evaporation, cutting; D = photoablation, photodisruption; E = formation of microplasms. [b] U = angioplasty, V = photodynamic therapy, W = urology - gynecology, X = gastroenterology, Y = ophthalmology, Z = dental medicine.