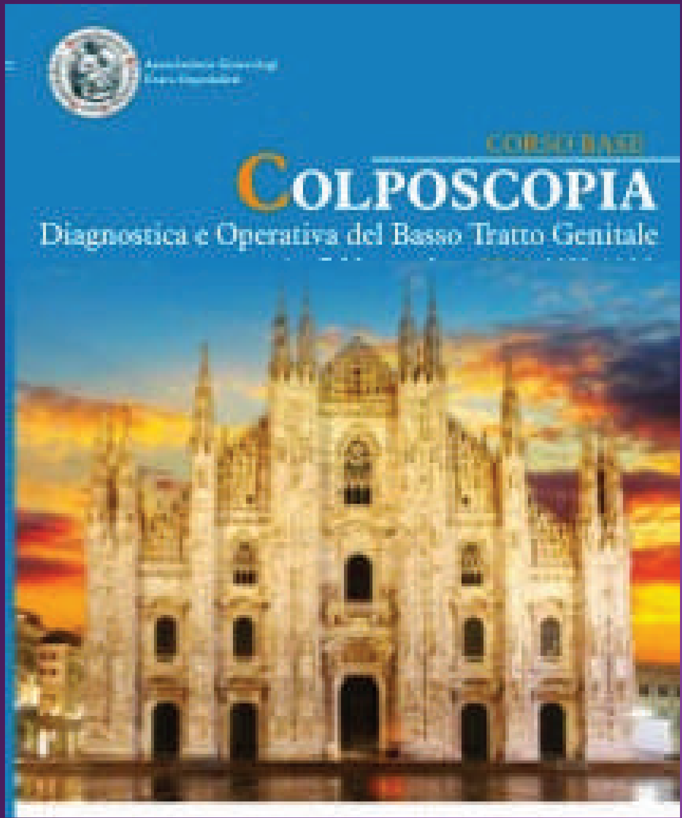
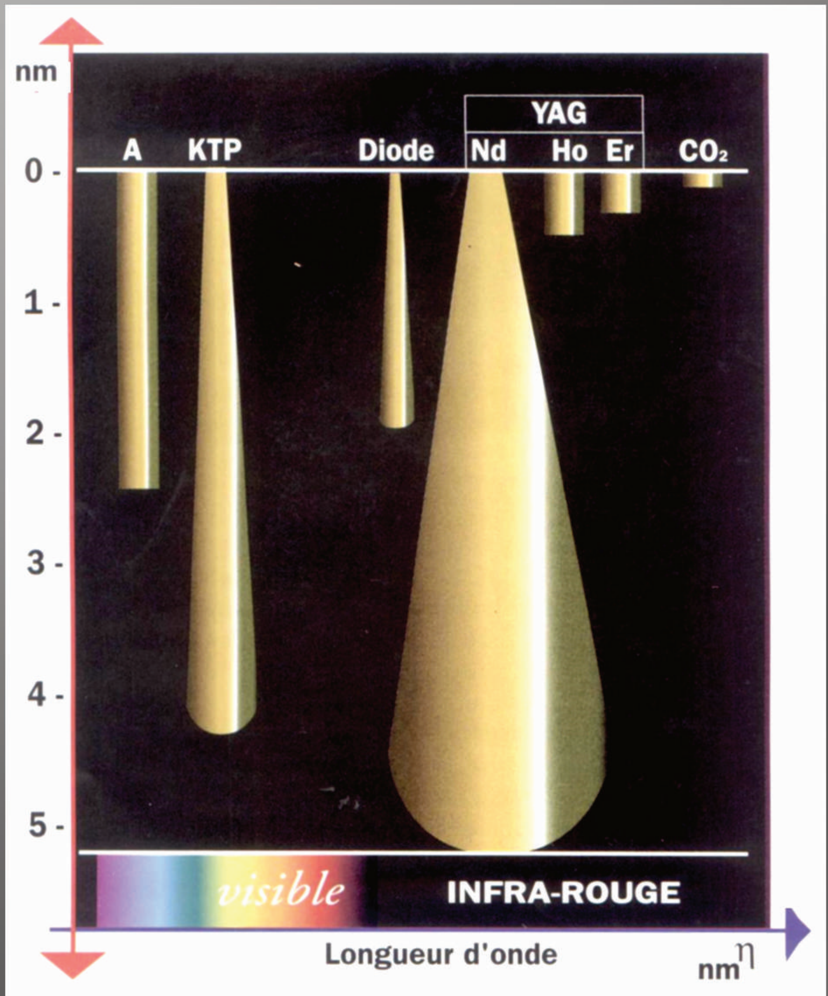


Principi di impiego del CO_2 laser

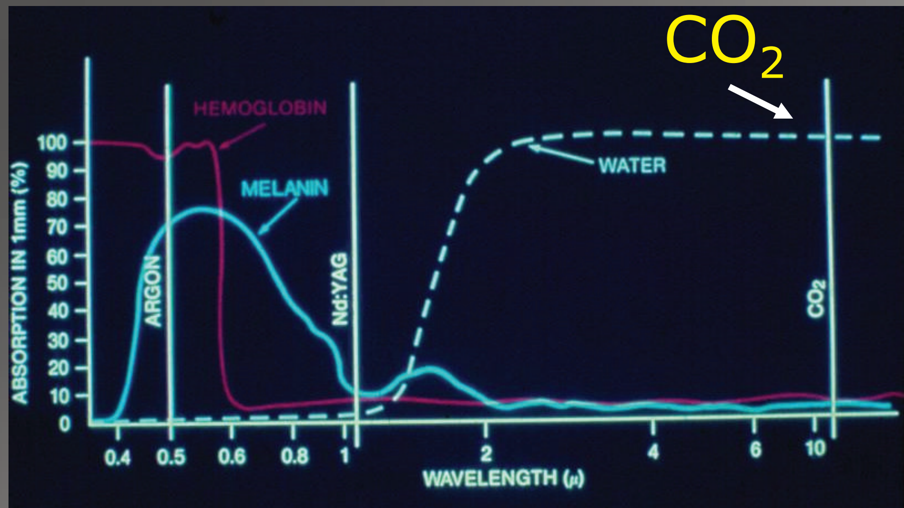
Dott. Gaetano Bandieramonte

Già Istituto Nazionale dei Tumori, Milano

Main Types of Surgical Lasers



	CO_2	Argon/KTP	Nd:YAG
Type	Gas	Gas	Crystal
Wavelength	10.6 microns	488-514 nm	1.06 microns
Color	Far Infrared	Blue-Green	Near Infrared
Power	0-100 W	0-20 W	0-150 W
Penetration	0.2 mm	1 mm	5mm
Absorbed by	Water	Hemoglobin & Melanin	Tissue Protein
Delivery	Articulated Arm	Optical Fiber	Optical Fiber
Aiming Beam	He-Ne	Argon	He-Ne
Energy Efficiency	20%	0.1%	2%
Maintenance	Moderate	High	Low
Cutting	Good	Poor	Fair
Coagulation	Poor	Fair	Good



The *extinction length* is defined as the thickness of water that absorbs 90% of the radiant energy of the incident beam.

For the CO2 laser, this is approximately 20μ

This property allows a potential for precise surgical control

Versatility and Selectivity of Lasers for Superficial lesions

Ablative (destruct.)	**Skin rejuven. rhytidectomy, resurf., (ablat. & non-ablat. techn.)**	• CO_2, 10600 nm • Er:Yag, 2940 nm • Nd:Yag,1064 nm, Q-switch • Nd:Yag, 1320 nm
	Pigment-targeted (Hair removal, long term epilation)	• Diode, 800 nm • Alexandrite, 755 nm • KTP, 532 nm • Nd:Yag, 1064 nm, Q-switch
	Tattoos removal	• Ruby, 630nm Q-switch • Dye Pulsed , 510 nm • Alexandrite. 755 nm, Q-switch
	Vascular-targeted	• Dye, 577,585,595,600 nm • Alessandrite, 755 nm • KTP, 532 nm • Diode, 810-940 • Krypton , 568 nm • Nd:Yag, 1064 nm
Excisional	**Lesion excision**	•CO_2, 10600 nm • Nd:Yag, 1064 nm

Main CO2 Laser terminology

Energy (E) — is power multiplied by time of application, expressed in *joule, (*J=1 watt (W) x 1 second (sec).

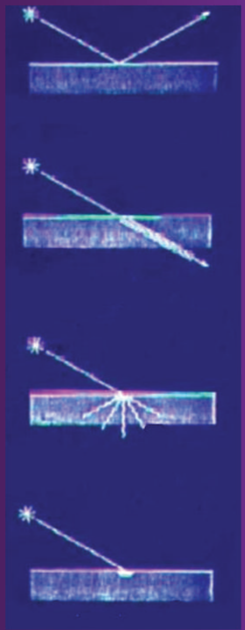
Power — energy divided by the time of application, expressed in *watt. 1 W* = 1 J divided by 1 sec. (J/sec).

Power Density (PD) — or ***irradiance**,* rate of power divided by the **surface area** of the beam or beam spot size (W/cm2).

Trasverse Electromagnetic Mode (TEM) — The cross irradiance in a gaussian fashion (TEM 00), or in a doughnut fashion (TEM 01)

Variables of beam emission — 1 Continuous Wave (CW); 2 Pulsed (super or ultra)

Laser Bioeffects

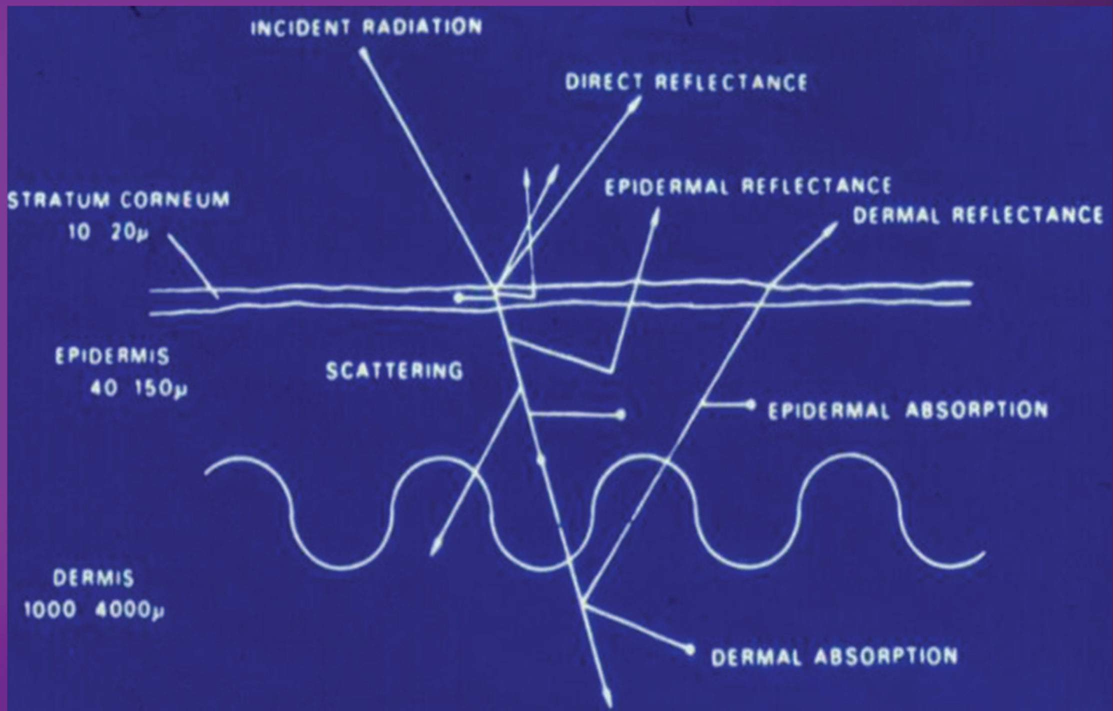


Reflection

Transmission

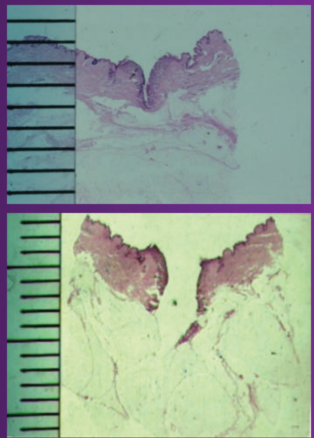
Scattering

Absorption



CO_2 Laser Bioeffects :
Main physical factors influencing the shape of the crater

CO_2 laser crater (stationary beam)

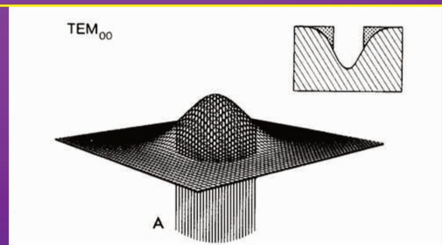


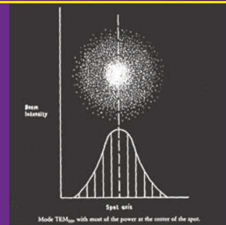
- Beam Spot Size → Width

- Exposure time
- Power Density
- TEM

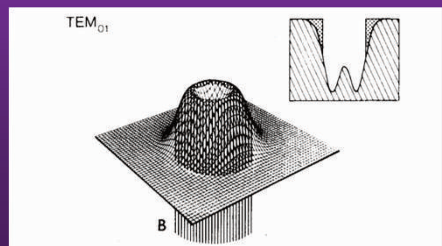
→ Depth

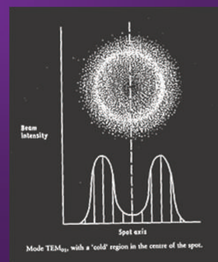
TEM 00: The irradiance across the beam is distributed in a **gaussian fashion** peaking at the center of the beam and falling off to zero at the edges.





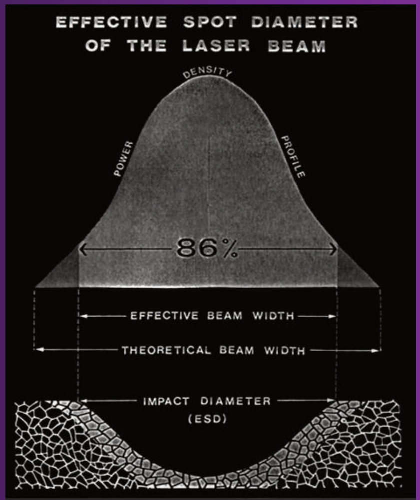
TEM 01: The irradiance across the beam is distributed in a **doughnut fashion,** peaking at the edges of the beam and falling off to zero at the center.

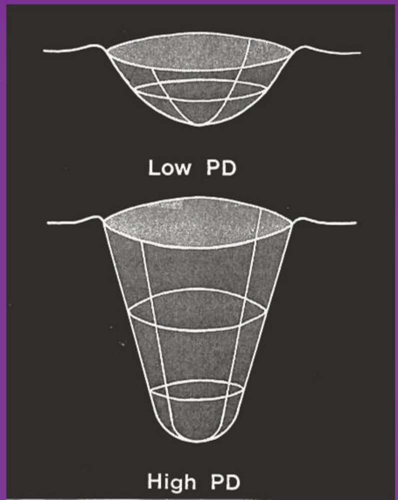


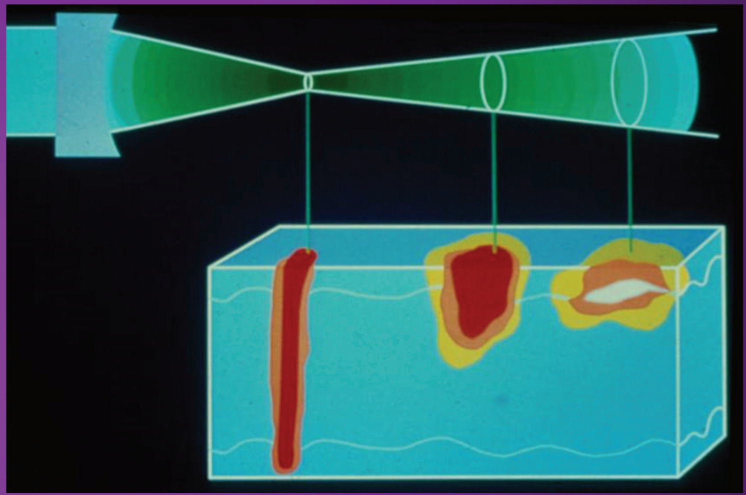


Spot Size

Controlled by **focusing lenses or by moving the handpiece toward or away from the target tissue**.
Small variations in distance and **angle of incidence** of the beam produces great alterations in the diameter of the beam spot size and consequently in power density, and crater configuration.

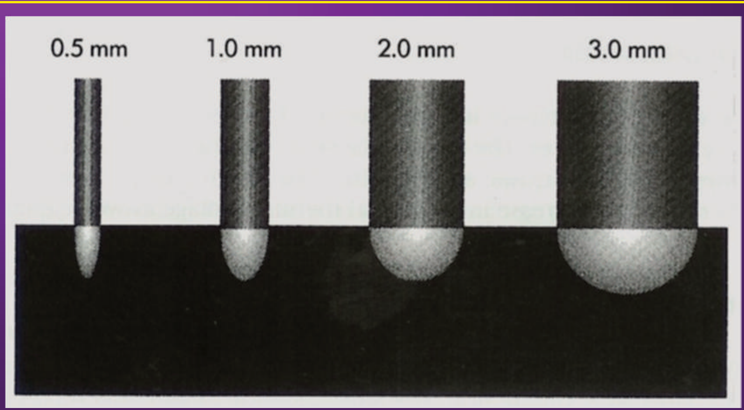






Smaller spot size creates incision, but bleeding.

Larger spot size allows for smoother, more uniform vaporization of tissue, but poor incision, and requires high power to compensate for the dilution of power density.



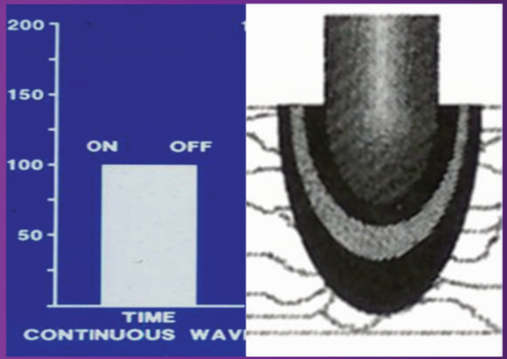
Variables of beam emission

Beam emission of CO2 laser surg. systems can be classified as follows:

1. **Continuous Wave (CW);**
2. **Pulsed (super or ultra)**

1. The CW:

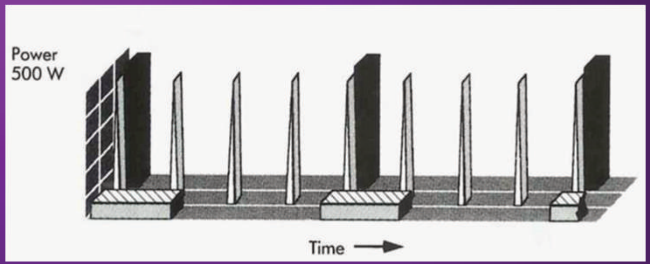
Hemostatic power for blood vessels of 0.5-2mm, but 500-3000 μm thermal damage, slower wound epithelialization, delay in epidermal migration (eschar), and increased wound infections.
Thermal damage caused by direct heating and peripheral heat conduction



2. Pulsed emission of CO2 laser for precise tissue ablation with decreased peripheral thermal damage.

Superpulsed or ultrapulsed CO2 laser emit a train of short-duration high-power pulses, produced by electronically pumping the laser tube.

The peak powers may be 10 times more than the CW mode laser



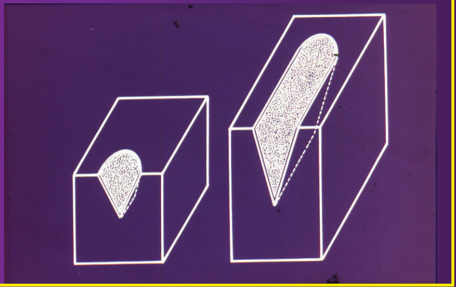
Fitzpatrick,1998

Laser-tissue interactions

The rate of irreversible cell injury increases as temperature increases.
The influence of temperature on tissue is a function of time:

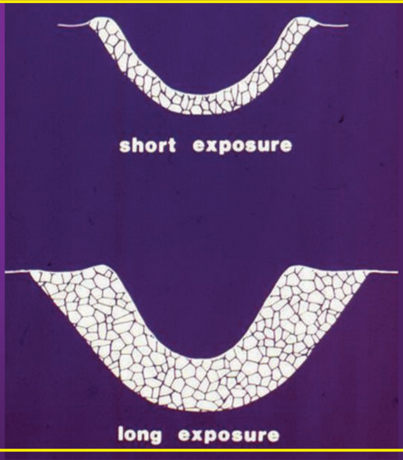
44° C=Lowest T° causing irreversible thermal damage in **7 hours**.
50° C, after **5 min.**;
60° C, after **5 sec.** (intracell. protein coagul.);
70° C, after **1 sec.**;
100° C, instant vaporiz. of intracell. water (**boiling point)**

Irradiance controls both the vaporization rate of tissue, and the depth of the vaporization crater (stationary beam) or incision sulcus (moving beam).

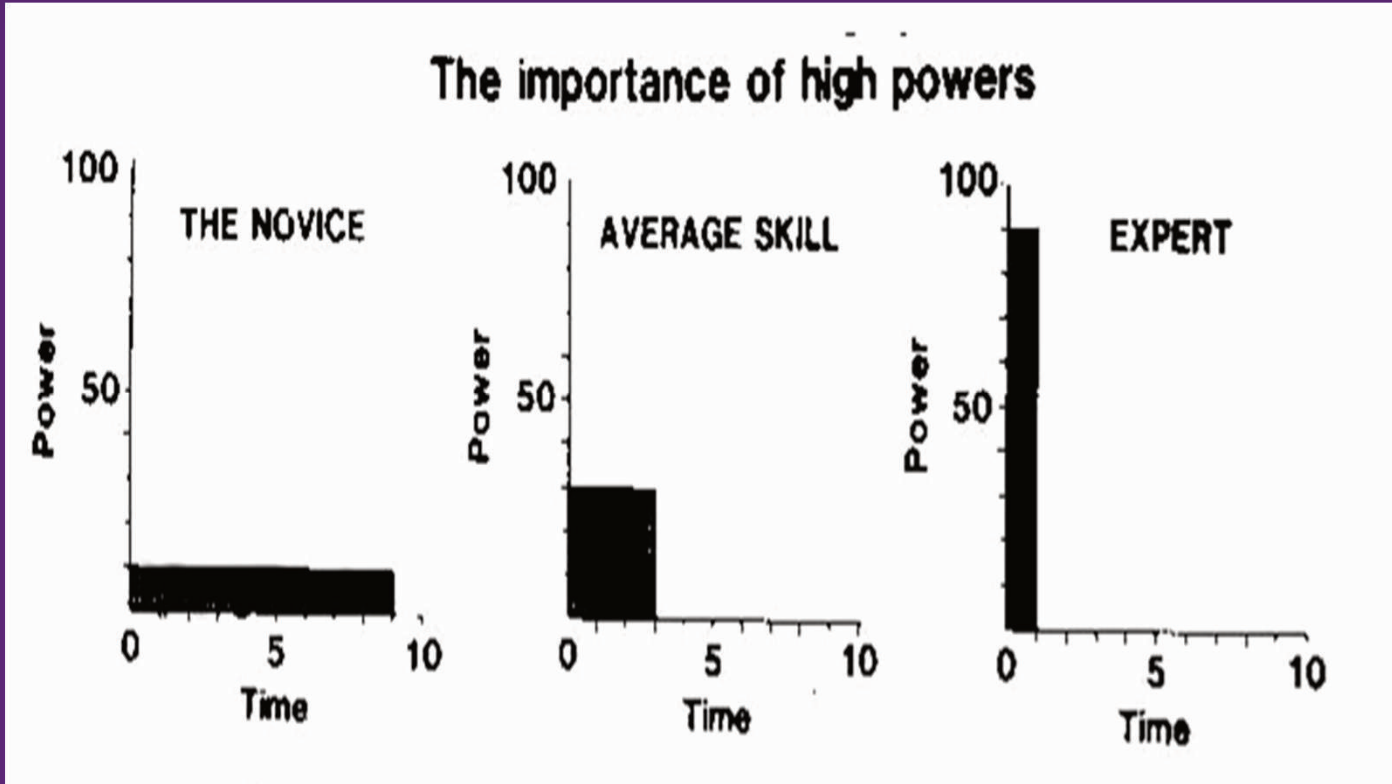


When tissue is heated slowly with low irradiance, charring occur with thermal diffusion similar to that of electrocautery, reaching temperatures of 300° -600° C, rather than 100° C required for vaporization. From thermal diffusion may results lateral thermal necrosis up to 1-3 mm.

High irradiance reduces thermal damage but requires a rapid speed with a continuous beam or a very short pulse of application.



Surgical effects



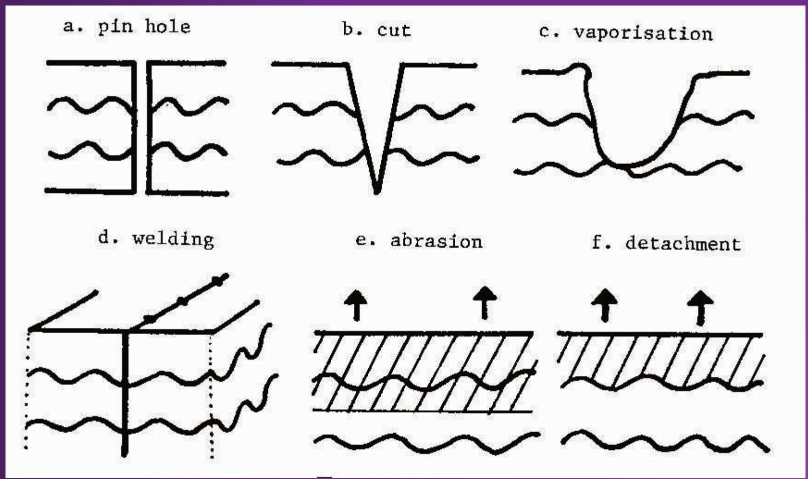
- **Best procedure for cutting or vaporizing when using the highest controllable irradiance (power density), within the effective beam spot Ø (the higher the power density used, the faster the beam has to be moved over the tissue surface)**

- **Minimal thermal damage when using high incisional speed**

- **Coagulation is performed at low power densities: by defocusing the beam to increase the spot ø, by reducing the power output, or both**

Surgical Effects

How laser works



Vessel coagulation

Shrinkage effect

The CO2 laser beam can be used:

- **with a focused spot size (0.1-0.2 mm) for incisional-excisional surgery**
- **with a large-Ø spot (2-5 mm) for precise and hemostatic ablation (destruction)**

The ultimate objective of lesion removal can be obtained either :

- **by contiguous movements of the laser until the tissue destruction at the desired plane is reached,**
- **or by direct excision under the desired level**

Destructive effects:
Ablation, Abrasion,
Vaporization
Photothermolysis

Excisional effects
Incision,
Resection

Combined effects
Excisional +Destructive

Limitations of the destructive technique:

1. **Lack of operatory specimen**

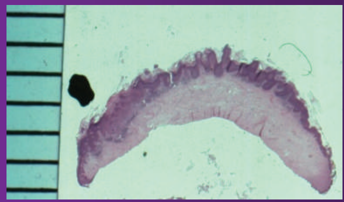
2. **Inter-operator variability, due to:**
   -Variable angle of beam incidence
   -Variable beam movement speed

3. **Time to vaporize the lesion increases with the lesion thickness,**
   Thin lesions (less than 1 mm) are difficult to be excised.

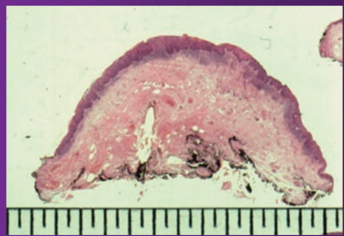
4. **Irregular lymphatic vessel sealing,**

Incisional procedure in healthy tissue is preferable for premalignant or initially invasive disorders, rather than vaporization.
The excision of tumor at a almost 1-2 mm distance out of lesion borders is advisable.

Tumor invasion
(unexpected)



Excision borders
in healthy tissue



Laser Plume

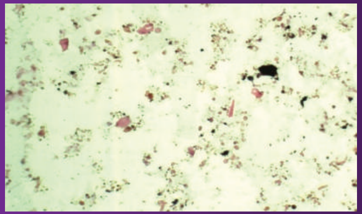
•**Plume of smoke** at the laser impact site during the vaporization of any tissue.
Intact cells are nonviable in the laser plume.

•**Particulate matter of 0.1-0.3 μm Ø** range, can produce lacrimation, nausea, cramping and vomiting, and may transmit infectious agents.

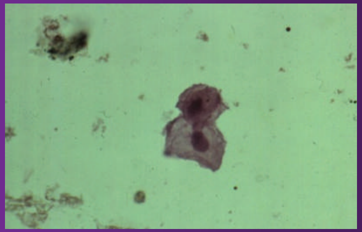
•**Bacterial spores** may survive in the plume at irradiances below 500 W/cm2, whereas at high irradiances the CO2 laser sterilizes and devitalizes exposed tissue.

•The risk of **HCV or HIV** potentially infectious particles is of negligible entity.
Viral DNA of HPV *can be found* in laser plumes from vaporized warts using both pulsed and CW irradiation at both high and low irradiances.
However, **HPV transmission** during a laser procedure has not been demonstrated.

Unrecognizable cell particles



Unviable cells



BIOLOGICAL SAFETY

(American Society of Laser Medicine and Surgery)

I. All laser plume are potentially hazardous

II. Evacuator suction system should be used to collect the plume.

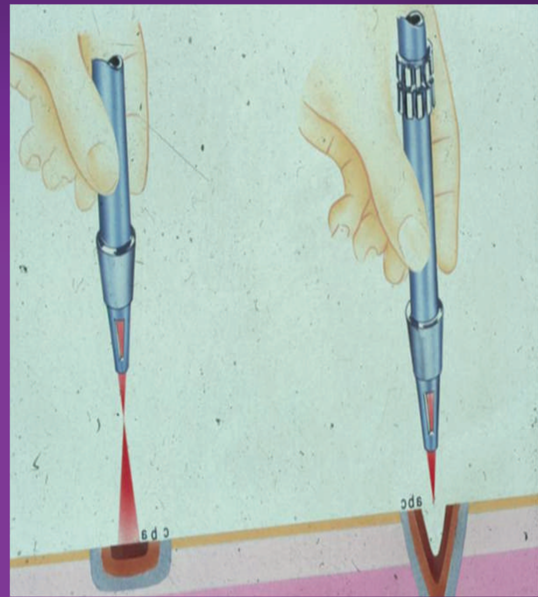
- A. Suction should have high flow volume with frequent filter changes.
- B. Filters should have maximum filtering efficiency (capacity for particles 0.1 μm, removal of 99% of plume matter)
- C. Suction tip must be placed close (1 cm) to laser impact
- D. Evacuator suction tips should be cleaned (sterilized) after each procedure.

III. Eye protection, masks, gloves, and gowns should be always worn during laser use by all laser personnel

- A. Eye protection should protect from splatter
- B. Masks should have effective filtration (over 99% of particles less than 0.5 μm in diameter or with an electrostatic filter to entrap the smallest particles (papillomavirus virions are 55 nm in diameter).
- C. Gloves should be preferable latex

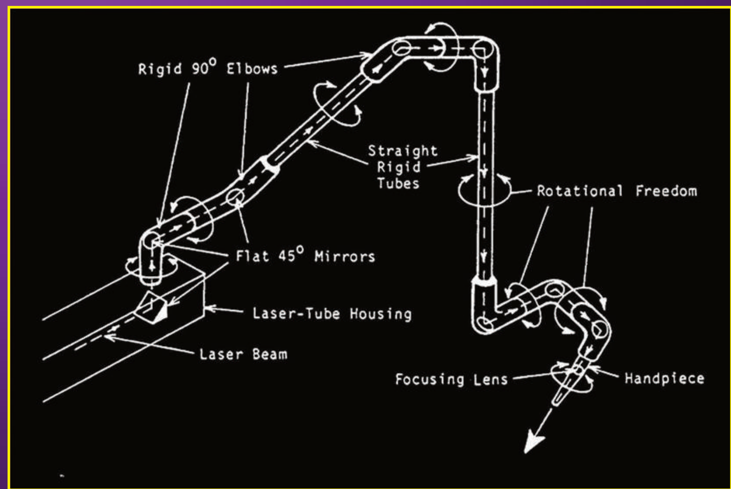
Laser safety: Suction device

Freehand Excision



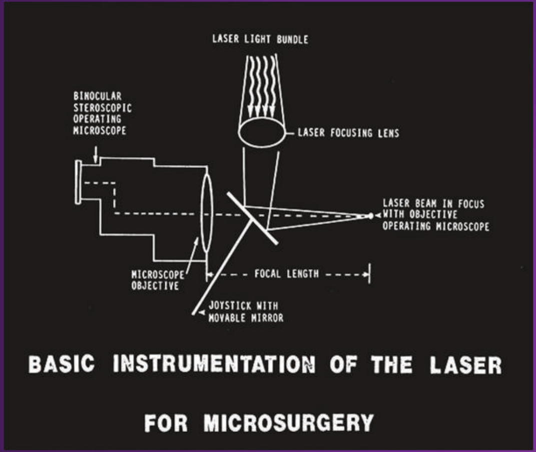
The delivery of the beam is accomplished by reflecting the beam by means of multiple mirrors, located inside of tubular articulated segments

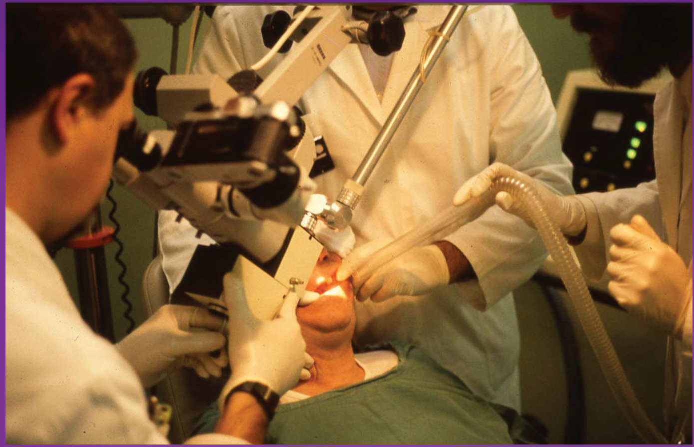
The surgical handpiece allow beam manipulation and freedom of surgical movement in the operatory field

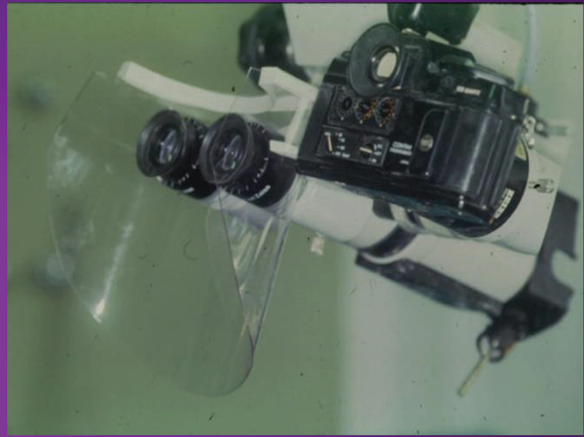


Microscopic versus Freehand Excision

Microscope coupled and micromanipulation technique







1. **Improved operative stability**

2. **Beam coaxial with microscopic viewing** and aiming beam visible through the optical lenses controlled with a **joystick,** distance 200-400 mm, magnif. power **6-40 X.**

3. **Improved lesion border differentiation, <u>selection of deep surgical plane</u> and *tridimensional control***

4. **Improved bleeding control, early visualiz. of small blood vessels**

5. **Reduced safety problems:** Lenses and facial mask protect the operator from smoke developed during surgery at the working distance

Safety & Good Clinical Practice

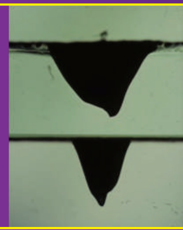
Classic Safety & Objectives

- Ambiente
- Operatore e Paziente
- Apparecchiature

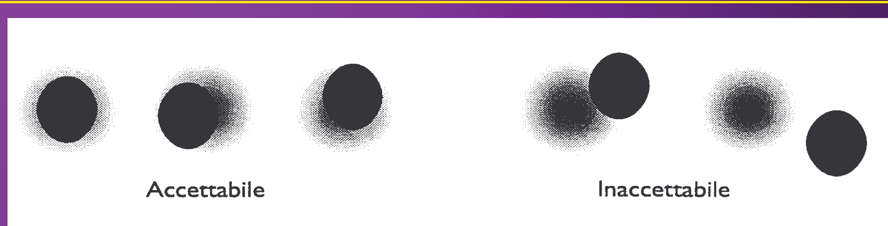
A. PHYSICAL Safety

Laser instrument and Accessories, (fiberoptics, operat. microscope, handpiece)

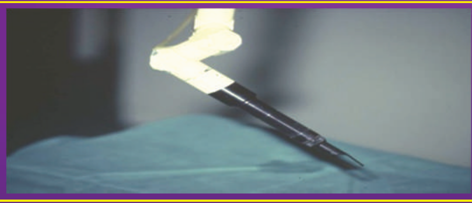
Controllo configurazione e stabilità TEM

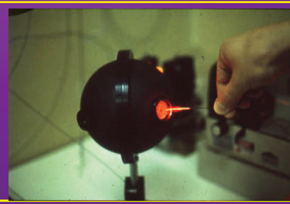


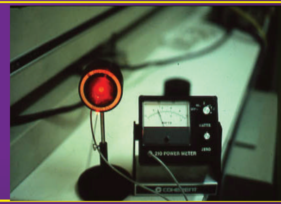
Allineamento CO2 ed He-Ne



Stand-by & power meter







B. BIOLOGICAL Safety

Critical organs by type of surgery

Standard eye protection (cornea)

Skin, Lungs, Others)

- Fumes and suction device

General Indications for Laser Clinical Applications

A) **Patient related** (pacemaker, contraindication for electrical instrumentation, bleeding disorders or assuming anticoagulants, contraindication of epinephrine for bleeding control)

B) **Anatomic related** (**critical sites** of the lesion for difficult surgical approach, or location particularly prone to bleeding because of the high micro-vascularization)

C) **Lesion related** (type and morphology)

D) **Technique related** (handpiece or microscope coupled, destructive or excisional, beam emission mode)

General Indications for Laser Clinical Applications

Lesion &Technique-related Indications for Laser application

1. Destructive (Vaporization):
- **-Histologically benign thin lesions**
- **-Surgical re-modeling of the wound after excision**

2. Excisional:
- **-Benign exophytic lesions (conservative)**
- **-In situ and micro-invasive lesions, especially of critical sites**

3. Combined (Excision+Vaporization)

Microchirurgia Laser

Metodica chirurgica che utilizza la strumentazione laser in associazione al microscopio operatorio o colposcopio.

Tale sistema operativo è particolarmente utile per interventi di precisione su microstrutture anatomiche, in sedi critiche, e per rimodellamento a scopo cosmetico.

Contraindications for precise microsurgical removal:

Infiltrating, not well-circumscribed (morpheic)

Manualità da sola non conta se indicazione è errata.

Si può eseguire intervento tecnicamente perfetto ma oncologicamente errato

Conclusioni

Raccomandazioni Generali

- Controllo dello strumentario prima dell'uso
- Controllo caratteristiche fascio laser (watt, spot, tempo)
- Allineamento fascio (visibile) di puntamento
- Occhiali protettivi
- Abilitare la sorgente sotto controllo operatore
- Rimozione fumi (0,1μm) e vapori

Algoritmo formativo

- prove su campioni inanimati
- prove su campioni anatomici
- interventi distruttivi superficiali
- interventi distruttivi profondi
- interventi escissionali

Svantaggi

- Costo e mantenimento apparecchiatura
- Norme di sicurezza
- Curva di Apprendimento
- Minore manovrabilità del sistema operativo

Vantaggi

- Precisione, specie con controllo microscopico
- Chirurgia conservativa / minima invasività
- Assenza di suture
- Possibilità di ri-modellamento cosmetico
- Controllo della lesione neoplastica

Grazie