Principi di impiego del CO2 laser

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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 20 µm. This property allows a potential for precise surgical control.
### Main CO2 Laser terminology

<table>
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<tr>
<th><strong>Energy (E)</strong></th>
<th><strong>Power</strong></th>
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<tbody>
<tr>
<td>is power multiplied by time of application, expressed in joule, ( J = 1 \text{ watt (W)} \times 1 \text{ second (sec)} ).</td>
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<tr>
<th><strong>Power Density (PD)</strong></th>
<th><strong>Trasverse Electromagnetic Mode (TEM)</strong></th>
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<td>energy divided by the time of application, expressed in watt. ( 1 \text{ W} = 1 \text{ J} \div 1 \text{ sec} ). ( (\text{J/sec}) )</td>
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<td>or irradiance, rate of power divided by the surface area of the beam or beam spot size ( (\text{W/cm}^2) ).</td>
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<th><strong>Variables of beam emission</strong></th>
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<td>The cross irradiance in a gaussian fashion (TEM 00), or in a doughnut fashion (TEM 01)</td>
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Categories for CO2 laser:
1. Continuous Wave (CW);
2. Computer assisted (scanning device);
3. Pulsed (super or ultra)
CO2 Laser Bioeffects:
Main physical factors influencing the shape of the crater

- Beam Spot Size
- Exposure time
  - instrument (beam emiss. mode)
  - operator (speed)
- Power Density
- TEM

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.
The spot size of the laser is 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 into the following categories:

1. Continuous Wave (CW);
2. Computer assisted scanning device with a CW emission;
3. Pulsed (a. super and b. 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.
3. Pulsed emission of CO2 lasers produce precise tissue ablation with decreased peripheral thermal damage.

Superpulsed or ultrapulsed CO2 laser can emit a controlled train of short-duration high-power pulses, produced by electronically pumping the laser tube. The peak powers are 10 times more than the CW mode laser.

Variables of beam emission

Ultrapulsed CO2 laser:
Thermal damage caused by direct heating

Continuous CO2 laser:
Thermal damage caused by direct heating and peripheral heat conduction
Surgical effects

- Best procedure for cutting or vaporizing when using the highest controllable power density, within the effective beam spot $\phi$ (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 $\phi$, by reducing the power output, or both
Surgical Effects

How laser works

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

Vessel coagulation

Shrinkage effect

Destructive effects:
Ablation, Abrasion, Vaporization, Photothermolysis

Excisional effects
Incision, Resection

Combined effects
Excisional + Destructive
Limitations of the destructive technique:

1. Lack of operatory specimen for complete histologic diagnosis, and removal completeness

2. Inter-operator variability, poor reproducibility, due to:
   - Variable angle of beam incidence (pencil like), with irregular ablation planes
   - Variable beam movement speed
   - Variable power densities, emission mode

3. Time to vaporize the lesion increases with the lesion thickness, and it is longer with respect to expert excision time. This is proportional to the lesion surface extension instead of the volume. But thin lesions (less than 1 mm in thickness) are difficult to be excised.

4. Lymphatic vessel sealing along the tissue edges are irregular findings, thus rendering the incisional procedure in healthy tissue as 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.
• **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 fluences the CO2 laser sterilizes and devitalizes exposed tissue.

• The risk of potentially infectious particles from patients infected with **HCV or HIV** is of negligible entity. **Viral DNA and virions 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.
1. 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.

2. Improved lesion border differentiation, selection of deep surgical plane and tridimensional control

3. Improved operative stability

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
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)
# 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