Carbon dioxide laser (CO2) has the optimal water absorption properties for laser skin resurfacing:

- 10,600 nm
- Effective for vaporization
- Significant, coagulation effect
- Thermal zones may be created and managed
Ablation (Vap.)
Necrosis

CO₂ Er:YAG

• 25 year evolution of CO₂ lasers, systems, and accessories for aesthetic and medical uses.
• Broad range of technology: 20 watts to 6,000 watts, DC, RF, Fast flow.
• Industrial, aesthetic, surgical, and dental systems

Versatility of CO₂ Lasers

Control of Thermal Zone

Operator can independently adjust ablation depth and thermal zone.

Benefits
• Control of ablation depth
• Control of thermal damage (hemostasis, collagen shrinkage)
• Intactness of the surrounding tissue
Thermal damage (Coagulation) = Ablation (Vaporization) = Skin

Independent control of depth of penetration and thermal damage zone.

Treatment techniques

Standard Skin Resurfacing

- Normal and homogeneous epithelial regeneration
- No photo-aging and no dyschromia
- No scars
- Surrounding tissue integrity

Parameters

- Power
- Dwell time

Collagen shrinkage
Neo collagenesis
Resurfacing Mode

Before
Immediately post
1 week post

After 4 weeks
After 6 weeks

Resurfacing Mode

Fractional Skin Resurfacing

Parameters

Power
Dwell time
DOT Pitch

Normal and homogeneous epithelial regeneration
Neither hyper nor hypopigmentation – No scarring
Reduced downtime
Collagen shrinkage
Neo collagenesis
**Fractional Skin Resurfacing**

- **Ablated tissue** (~3% - 35%)
- **Spare tissue** (~65% - 97%)
- **Power**
- **Dwell time**
- **DOT pitch**
- **Collagen shrinkage**
- **Neo collagenesis**
- **Reduced downtime**

**Fractional Skin Resurfacing**

1. Shrinkage of collagen fibers
2. Proliferation
3. Remodeling

- **Collagen shrinkage**
- **Neo collagenesis**
- **Epithelialization**
- **Thermal damage**
- **Riepithelization**

Immediately after 2 days after 7 days after

In FPT, heat is delivered to the tissue in columns rather than in layers.

**SAFETY**

- **EFFICACY**
  - **ABLATIVE**
  - **MINIMALLY ABLATIVE (FPT)**
  - **NON-ABLATIVE**

**Safeguards:**

- High safety is maintained through:
  - Treatment dosimetry to limit injury to normal tissue.
  - Percutaneous treatment approach to limit injury to normal tissue.
  - Appropriate monitoring of normal tissue.
Physics Terms

Power – watt (W) – rate of work, rate of energy conversion.
Irradiance – W/cm² – power per unit area at a surface, power density.
Energy – joule (J) – amount of work done.
Fluence – J/cm² – measurement of energy flow across a unit area.
Thermal Conductivity – W/cm°C – unit of the ability to conduct heat.
Heat Capacity – J/cm³°C – ability to store heat for a unit temperature rise.
Thermal Diffusivity – cm²/s – ability for a material to adjust its temperature to its surrounding. Ratio of Thermal Conductivity to Heat Capacity.
Thermal Relaxation Time – s – the time for the temperature difference between and object and the initial temperature of its surroundings to decrease by 1/e.

*the symbols for watt (W) and joule (J) should be capitalized.

Fractional Laser Treatment

A fraction of the skin area is treated with an array of relatively small spots.

Fractional – of, relating to, or being a fraction
Relatively small: inconsiderable
Fractionate
- to divide or break up
- divide into different portions

Note: the term fractionated is sometimes used, however it is a less accurate description of the process. Dividing a treatment area into cosmetic units for full resurfacing could also be considered as a fractionated treatment by definition.

Fractional Tissue Parameters

Pitch – dot spacing, sometimes density or (dots/area) is used.
Spot size – no standard definition
- diameter of the ablation channel,
- diameter of the total injury
- diameter of the laser beam
Ablation depth
Thermal Damage Zone (TDZ) or Coagulation – comprises the necrotic zone and as well as viable thermally modified tissue.

Note: These parameters define the basic treatment. Two different lasers will give similar results if they have similar values for these four parameters.
Diameter of Injury
a. Diameter of ablation channel
   - Common understanding
   - Difficult to measure and may vary with laser power
b. Diameter of total injury
   - More significant clinically than ablation diameter
   - More difficult to measure and define

Diameter of Laser Beam
a. "Diameter containing > 90% of energy" – good for most beams
b. 1/e² power point
   - Not appropriate for many beam shapes including flat top beams
c. Diameter determined by observed impact
   - Subjective and inappropriate for gaussian-like beams.

Note: Laser diameter (a.) is precise and reproducible, and a good parameter for comparing devices. It is very close to the diameter of ablation and easier to measure for comparing devices.
The image shows the ablation channel width of about 150 µm created with the Smartxide DOT ex-vivo in tissue with a 5 micropulse burst (Stack 5 setting) in fractional scanning mode.

Channel sizes < 300µm heal quickly and are unnoticeable.

Channel sizes > 300µm can sometimes leave noticeable patterns long after healing.

Note: Spot size is less important clinically than percentage of area covered including the amount of thermal coagulation.

Reference: “In vivo histological evaluation of a novel ablative fractional resurfacing device”

Pitch or Density

Pitch = dot spacing in microns or mm
Density = dots per unit area = 1/pitch²

Area treated = (Spot Area) X (Density)

More area treated > More dramatic results > Longer recovery

Note: A wide range of spot density options is important to match the ideal treatment to the condition.
Laser Control Parameters

Parameters that Control Tissue Ablation

**Beam size**
- Measurable and correlates with the diameter of the ablated channel.

**Power to tissue, or irradiance**
- Determines the rate of ablation.
  - High power beams vaporize tissue faster than low power beams.

**Dwell time**
- Determines the loss of heat due to conduction
- Determines the depth of ablation if beam power is known

**Dot pitch**
- Controls the amount of area treated for a given spot size

Laser Derived Parameters

**Measured or calculated parameters**

**Pulse Energy**
- the Power and the Dwell Time.
  - Correlated with the total amount of work done to tissue.
  - Either the Dwell Time or the Power must also be known to understand the Clinical Significance of Pulse Energy.
  - Any laser can deliver any pulse energy if left on tissue long enough.

**Average Power**
- the average of the beam power including ON and OFF time.
  - This has little to no Clinical Significance and is related to the maximum wall plug power required by the system.
  - Most laser devices specify the maximum average power that can be delivered.
  - Usable average power is much less than the rated average power and is limited by treatment, delivery systems, and usability.

Note: Pulse Energy and Average Power are not reliable indicators of relative device performance.

Trade Names & Marketing Terms

Superpulse, Ultrapulse, Chopped-Pulse, Gated-Pulse, CW are marketing or trade terms.

- Almost all medical CO₂ lasers can operate in both CW and Pulsed modes.
- The critical parameters are:
  - Pulse height (power) and Pulse width (time)
- Some lasers can have modulated pulses for added features.
Laser Pulse Shape

There are two Significant Physics Parameters

1. **Pulse Height** – Irradiance
   (Power/Area)
   Determines ablation rate, or rate of thermal energy deposited, and is the power to tissue.

2. **Pulse Width** – Dwell Time on Tissue
   Governs the amount of energy used, or work performed on tissue at a specific irradiance level.

Pulsed CO₂ Laser Classification

CO₂ lasers can be classified by pulse capability

**TYPES of PULSING**

1. Gated-CW (chopped-CW)
2. Variable-CW
3. Enhanced Pulse
4. Modulated Pulse

**Gated- or chopped-CW**

- Pulsed by gating on and off.
- Laser runs at nominal fixed power when on.
- Energy delivered is determined by gated on-time.

Typical operation of RF-excited lasers such as Lutronic eCO₂, and Fraxel re:Pair, and the Lumenis UltraPulse, which is a 200 watt CW laser that can be gated on for up to a millisecond.
Pulsed CO$_2$ Laser Classification

**Variable-CW**
- Pulsed by gating on and off
- Laser power can be varied for additional control
- Typical operation of DC-excited lasers.

More control over parameters than typical RF-excited lasers.

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Pulsed CO$_2$ Laser Classification

**Enhanced Pulse**
- Sometimes referred to as Superpulse.
- Laser tube gas volume is larger than needed for CW operation.
- Tube can deliver very high powers for very short times.

Typical of some DC-excited tubes such as Smartxide DOT

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Pulsed CO$_2$ Laser Classification

**Modulated Pulse**
- Custom pulse shape superimposing more than one mode of operation.
- DEKA SmartPulse uses an enhanced pulse for high-power ablation and variable-CW energy for coagulation.
- Sciton Contour and Lumenis Derma-K are examples of early modulated lasers for full resurfacing.

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Misconception

Selective photothermolysis can be used to describe the residual thermal damage for CO\textsubscript{2} lasers.

The theory is not applicable. For 3 reasons:
1. The energy from a CO\textsubscript{2} laser is mostly non-selective in tissue.
2. Much of the target is removed from surrounding tissue as well as the energy that the target absorbed.
3. A directly-heated tissue layer and a conductively-heated tissue layer remain after ablation and subsequently heats deeper layers of tissue.

This is a far more complex process* than the model described by the theory of selective photothermolysis.


Depth of Ablation

The Smartxide DOT is a high performance CO\textsubscript{2} fractional system that can give consistent ablation channels to over 1mm in depth.

Depth is correlated with peak power and pulse width.

Note: Anecdotal correlation of depth with efficacy.

How Deep is Enough?

Laser Resurfacing depth:
- 20 to 150 \textmu m of ablation*
- 20 to 150 \textmu m thermal damage*

Result of patient treated with Smartxide DOT in resurfacing mode.

Depths of 300\textmu m can give dramatic clinical results

Transform Your Patients

Upper Lip: 30W – 1000 Dwell – 500 Spacing

Used with permission of C. William Hanke, MD

Misconception

Deeper is better. Depths of 700µm or greater are required for CO₂ fractional resurfacing.

Many examples contradict this. A controlled study is needed.
1. Dramatic CO₂ resurfacing results obtained at <700 µm.
2. Results with Smartxide DOT up to 400 µm with added thermal damage show good patient improvement.

Acne scars, burn scars and other conditions may require deeper treatment, but so far there is no indication that deeper is better.
<table>
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<th>Requirement</th>
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<td>Laser type</td>
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<td></td>
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<td>many other surgical uses</td>
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<td>Spot size</td>
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<td>Ablation depth</td>
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<tr>
<td>Tx time</td>
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Thank You

Questions?