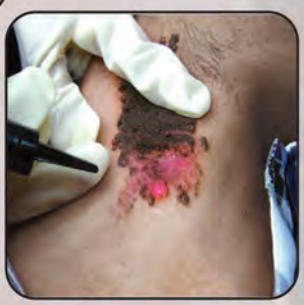
LASERS & ENERGY DEVICES in Aesthetic Dermatology Practice



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CHAPTER 4

Fractional Photothermolysis

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OVERVIEW

This technology has its genesis in the attempt to overcome the disadvantages of conventional ablative and nonablative laser therapies. The basic concepts for these studies were introduced in 2003 and reported in full during 2005 (Huzaira M et al.). Manstein and colleagues introduced fractional photothermolysis (FP) in 2004 with their original prototype FP device. The initial studies were restricted to the forearm skin and periorbital rhytides, but the same principles apply to facial skin where the most common indication is acne scarring (Tannous Z et al.).

The *chromophore* for fractional photothermolysis is *tissue water* with targets being epidermal keratinocytes, dermal collagen, and dermal vascular structures. Unlike bulk heating of ablative devices, fractional photothermolysis capitalizes on untreated tissue to accelerate wound healing. This action of the laser, where only a *fraction of the epidermis is damaged*, is the genesis of the term fractional laser.

SCIENTIFIC LOGIC

The scientific concept underlying FP involves the application of microscopic beams of pixelated light, which induce small and focal zones of tissue injury. Because the pixelated zones of treatment spare surrounding normal tissue, reepithelialization occurs at a significantly faster pace. The tissue injury created with FP stimulates the process of collagen remodeling and deposition and promotes elastic tissue formation. These molecular changes are postulated to be responsible for the clinical improvements seen with FP. A comparison of various fractional laser technological systems is given in Table 4.1 and is depicted in Figure 4.1. Nonablative lasers are discussed in a separate chapter.

Arrays of microscopic columns of thermal injury (MTZ) (Fig. 4.1) surrounded by intact tissue are the hallmark of fractional photothermolysis. The *depth* of the MTZ may vary and depends on various *factors* including

Table 4.1: Comparison of the nonablative and ablative fractional lasers with traditional ablative lasers (Narukar et al).

	Nonablative fractional (NAFR) lasers	*Ablative fractional (AFR) lasers*	*Ablative lasers*
Wavelength	1,540 nm, 1,550 nm	2,940 nm, 10,600 nm	2,940 nm, 10,600 nm
Type	Fractional, nonablative	Fractional, ablative	100% coverage ablative/ pseudofractional, ablative
S. corneum damage	No	Yes	Yes
Downtime	None	48 hours	4–7 days
Avoid Sun	1–3 days	5 days	2.5–4 weeks
Depth	1.4 mm	1.6 mm	1 mm/pass (laser dependent)
Dermal damage	No	Yes	Yes
Number of sitting	3–5	1	1
PIH	No	No	Yes

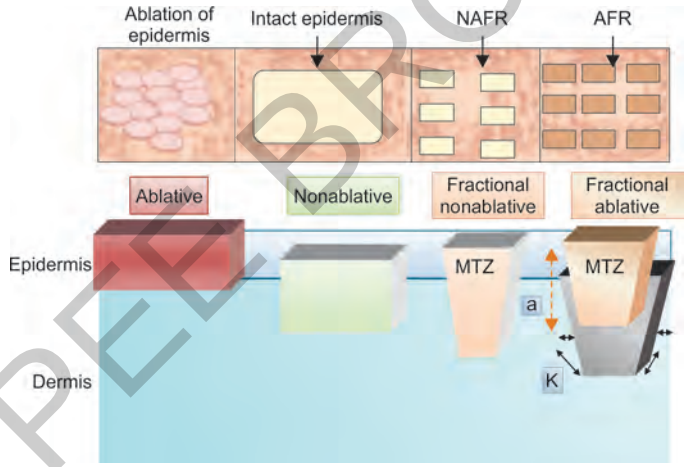

Fig. 4.1: A comparison of various ablative and nonablative lasers. a = zone of ablation, k = zone of coagulation. Ablative lasers (total ablation of epidermis), nonablative lasers (subsurface effect, epidermis is intact), NAFR (columns are formed with intact stratum corneum). AFR (columns with loss of stratum corneum and zone of coagulation) (MTZ: microthermal zone; NAFR: nonablative fractional laser; AFR: ablative fractional laser)

wavelength, dose, pulse duration, density, and temperature of the target tissue. The shape of such MTZs is either an inverted cone or a tapered column extending into the dermis. The histological effect is that of microscopic epidermal necrotic debris (MEND) which shuttles out within 24 hours followed by collagen regeneration, which may take months (Figs. 4.2A and B). The rapid tissue healing is because a fraction of the skin is damaged and thus ensures rapid healing, which forms the basis of fractional lasers (Fig. 4.3). The MTZ zones repair and heal rapidly usually within 24 hours.

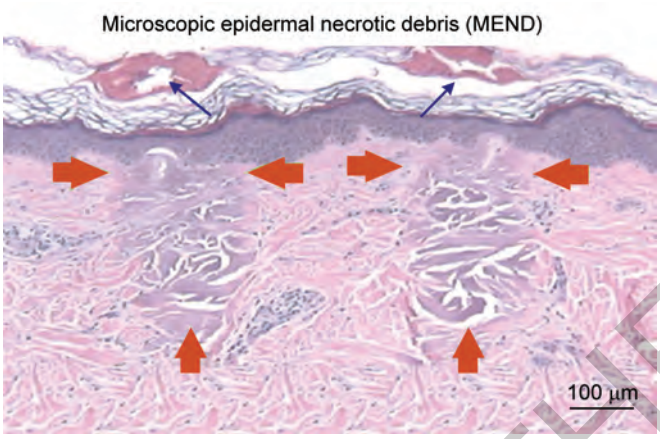

Fig. 4.2A: Controlled zones of denatured collagen in the dermis.

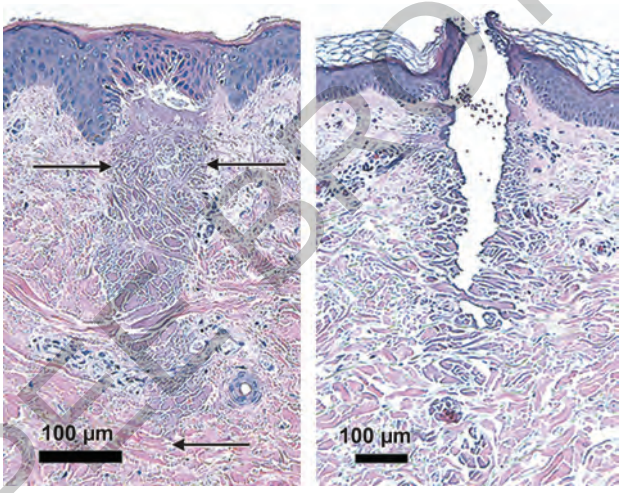

Fig. 4.2B: Histology of treated areas by nonablative fractional resurfacing and ablative fractional resurfacing.

ETHNIC SKIN AND FRACTIONAL LASERS

Ethnic skin is unique in that increased epidermal melanin and melanocyte reactivity results in a pronounced tendency to hyperpigment in response to trauma or light stimuli that can be persistent. Features of aging and cosmetic desires for the Asian population are also distinct from Caucasians. Photodamage is typically manifested as *pigmentary aberration* rather than rhytides. Lentigines, Hori's macules, and melasma are common cosmetic concerns. Wrinkling is encountered about 10–20 years later compared to age-matched Caucasians. With the limited efficacy of nonablative technologies and unacceptably high-risk profile of FA, fractional photothermolysis has found favor.

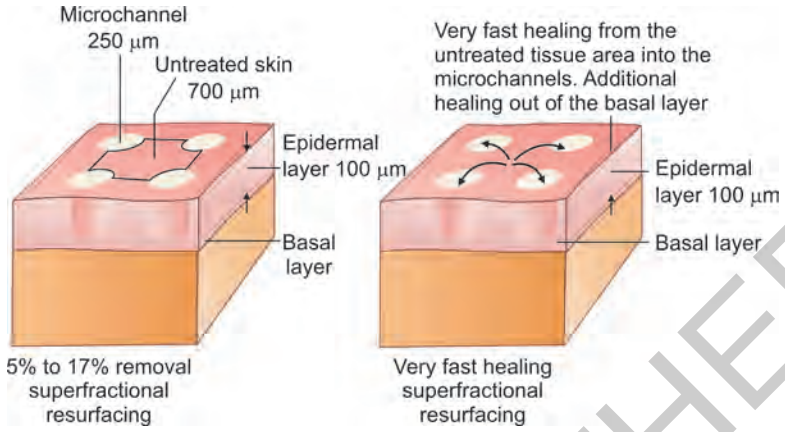

Fig. 4.3: Diagram depicting the regeneration of damaged tissues consequent to fractional laser therapy.
Source: Asclepion Laser Technologies, GmbH.

The formation of microscopic columns of ablative and/or coagulative damage, termed microthermal zones (MTZ), is the fundamental basis of fractional technology. In case of nonablative fractional lasers, columns of coagulative damage are seen traversing the epidermis and dermis but sparing the stratum corneum. By 24 hours, there is formation of microscopic epidermal necrotic debris (MEND) within the epidermis, which serves as shuttles for the transepidermal elimination of coagulated epidermal/dermal material and melanin (Fig. 4.2A).

Genetic analysis of ex vivo skin from Asian patients *24 hours* post-AFL is also demonstrated upregulation of key players in wound healing including metalloproteinases-1 and 3 (MMP-1, MMP-3) and procollagens I and III. Simultaneously, keratinocytes adjacent to each microscopic column migrates and rapidly repopulates the epidermal defect within 24 hours. Preservation of the epidermal barrier allows for greater treatment depths to be achieved safely while also reducing adverse effects and down time. Complete extrusion of MENDs is seen in *7 days*.

The effects of a fractional treatment can be divided under the following steps:

- Repair of the dermal portion of MTZs requires *4–6 weeks*, which corresponds to when clinical benefits first become evident.
- Thermal ablation results in sequentially additive neocollagenesis and collagen contraction that can be seen up to *6 months* following traditional ablative therapies. Procollagens I and III mRNA may reach 8–9 times the baseline levels from 3 weeks up to 6 months post-treatment explaining the prolonged treatment effects.

- Histological studies on Asian patients found significantly increased levels of heat shock protein (HSP)-70 expression, neocollagenesis, and formation of nascent elastic fibers at *1 month* following AFL, which persisted at 6 months following treatment.

FRACTIONAL VERSUS SELECTIVE PHOTOTHERMOLYSIS

Fractional photothermolysis (FP) is distinct and yet similar to the well-known process of selective photothermolysis (SP) originally described over 20 years ago (Manstein D, et al.) (Table 4.2). Both SP and FP cause small, spatially limited zones of photothermal effects within tissue due to local energy deposition. Widespread clinical use of SP for decades has shown that this type of injury is very well tolerated; the same is true for FP. In any photothermal process, including SP and FP, distribution of thermal excitation is proportional to the product of the local optical energy density times and the local optical absorption coefficient. While SP relies on selective absorption of a largely uniform optical field by pigmented target structures, FP relies on optical foci within a largely uniform medium. It should be noted that SP and FP are conceptual descriptions of idealized situations (Table 4.2). In practice, neither the medium nor the optical field is ever completely homogeneous.

Table 4.2: Difference between selective photothermolysis and fractional photothermolysis.

Characteristic	*Selective photothermolysis (SP)*	*Fractional photothermolysis (FP)*
Optical field in medium	Homogeneous	Focused beam
Optical properties of medium	Local absorbers	Homogeneous
Confined thermal damage	Target chromophore	Optical focus regions

CLASSIFICATION OF FRACTIONAL TECHNOLOGY

There are broadly two types of fractional lasers:

- Nonablative fractional laser, and
- Ablative fractional lasers.

A list of some of the leading fractional laser manufacturers is given in Table 4.3 for quick reference.

Nonablative Fractional Resurfacing

True NAFR requires three criteria:

1. Nonablative mode of tissue coagulation with the stratum corneum remaining intact and the tissue not being vaporized (Fig. 4.2B)
2. Creation of multiple microthermal zones surrounded by islands of viable tissue, and

Table 4.3: A summary of fractional lasers with their specifications.

Laser company	*Wavelength and pulse duration*	*Mode*	*Diameter/depth*	*Energy (mJ/MTZ)*	*Density/(cm^2)*	*Fractional coverage of skin surface at end of one session (%)*
Nonablative Fractional Lasers						
Affirm (Cynosure)	1,320/1,440 nm Nd:YAG	Stamping	100 µm/ 200–300 µm	8–12	1,000 mb/cm^2	10–30
Fraxel re:store (Solta)	1,550 nm Nonablative True fractional	Scan	100 µm/ 500–1200 µm	8–40	250 mb/cm^2	12–20
Fraxel re: fine (Solta)	1,410 nm Er: Glass	Rolling		5–20		
Fraxel restore DUAL	1,550/1,927 nm Er: Glass/thulium	Rolling	135–600 µm	4–70 5–20		
Lux (Palomar)	1,540 nm Nonablative true fractional Er: Glass	Stamp	125–200 µm/ 125–850 µm	70–100	100–320 mb/cm^2	10–25
Lutronic (Mosaic)	1,540 nm Nonablative true fractional Er: Glass	Scanned stamping	220 µm/ Up to 1,000 µm	5–40	100–500 mb/cm^2	NA

Contd...

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Laser company	*Wavelength and pulse duration*	*Mode*	*Diameter/depth*	*Energy (mJ/MTZ)*	*Density/(cm^2)*	*Fractional coverage of skin surface at end of one session (%)*
Matisse (Quanta)	1,540 nm Nonablative true fractional Er: Glass	Stamp	100 µm/ 30–150 µm	5–20	1,000 mb/cm^2	NA
Protocadmus	1,545 nm Er: Glass	Stamp	NA	NA	NA	NA
Sellas	1,550 nm Er: Glass	Scanned stamping	Size: 312–1,000 µm	1–300		
Ablative Fractional Lasers Er: YAG						
MCL 30 MCL 31 Ascepelion (variable pulse duration)	2,940 nm (100–1,000 µs)	Stamp	100 µm/ 200–300 µm	8–12	1,000 mb/cm^2	10–30
Lux 2940 (Palomar)	2,940 nm (0.2–5.0 ms)	Scanned	100 µm/ 500–1200 µm	8–40	250 mb/cm^2	12–20
Profractional (Sciton)	2,940 nm	Stamp	125 µm–200 µm/ 125–850 µm	70–100	100–320 mb/cm^2	10–25
Pixel (Alma)	2,940 nm (1–2 ms)	Scanned	220 µm/ Up to 1,500 µm	5–40	100–500 mb/cm^2	NA

Contd...

Contd...

Laser company	*Wavelength and pulse duration*	*Mode*	*Diameter/depth*	*Energy (mJ/MTZ)*	*Density/(cm^2)*	*Fractional coverage of skin surface at end of one session (%)*
Ablative Fractional Lasers CO_2						
Active Fx Lumenis (1.3 mm spot size) Deep Fx (Spot Size = 0.12 mm) SCAAR Fx	10,600 nm (<1 ms)	Scanned paint brush	• 1300 µm/10–300 µm • 120 µm/150–1,600 µm • 120 µm/4,000 µm	60 W		30–60
AcuPulse (SuperPulse)	0.3–0.5 m		0.12 mm and 1.3 mm/1mm	40 W	225 mJ	
Fraxel repair (Solta)	10,600 nm (0.15–3 m) (0.8–1.8 m)	IOTS (paintbrush) continuous motion	140 µm/1,600 µm	40 W		5–50
Smartxide Dot (Deka)	10,600 nm (200 µs-2.0 ms)	Scanned conventional	350 µm/ 500–800 µm	30 W		
Youlaser CO_2 (Quanta)	10,600 nm	paint brush		30 W		
Quadralase (Candela)	10,600 nm	paint brush motion	Ablation depth 30–750 µm	60 W	30–90 mJ	5–30

Contd...

Contd...

Laser company	*Wavelength and pulse duration*	*Mode*	*Diameter/depth*	*Energy (mJ/MTZ)*	*Density/(cm^2)*	*Fractional coverage of skin surface at end of one session (%)*
Mixto SX (Lasering)	(2.5–16 ms)	Scanned (four quadrants)	180 µm/200 µm	0.5–30 W		
Multipulse (Ascepelion)	0.2–2.0 ms		350 µm 500–800 µm	30		
ProFrax C_2 Protocadmus	1–50 ms		5–10 µm Up to 5,000 µm/			
eCO_2 (Lutronic)	Variable	Stamping dynamic	120–1,000 µm/ 2,500 µm	30 W		
Ablative Fractional Lasers Fractional YSGG laser						
Pearl (Cutera)	Variable	Scanned	300/1,500		60–320 mJ/ microspots	

*As laser treatment depends on various parameters and novel devices are added, it is advisable to refer to company manuals for device-specific settings to optimize depth and results.

3. Resurfacing with extrusion and replacement of damaged tissue, with reepithelialization within 24 hours (*see* Figs. 4.1 and 4.3).

The major conundrum is to balance the minimal clinical effects, which are usually seen with traditional nonablative modalities resulting in disappointing clinical results, and blistering, which produces an ablative-like response.

In the Asian population, NAFL may be considered a *first line* treatment for atrophic scarring and wrinkle reduction. The favorable side effect profile and low risk of dyspigmentation make it the preferred option for the majority of Asian patients seeking photorejuvenation as well. NAFL may be reserved as a *second-line* modality for the treatment of recalcitrant melasma.

Systems and Devices

The basic concept is to use a wavelength with optimal mid-dermal penetration. These include the 1,320-, 1,410-, and 1,440-nm Nd: YAG laser, the 1,450-nm diode laser, and the 1,535-, 1,540-, and 1,550-nm ytterbium: erbium-phosphate glass (also known as erbium: glass or Er: Glass) laser.

1. ***1,320-nm Nd:YAG Laser:*** It typically leads to an epidermal heating of 40–50°C accompanied by a temperature elevation within the dermis up to 70°C with a fluence of 12–18 J/cm^2 (17–19 J/cm^2 CoolTouch3, CoolTouch^0 Corp, Roseville, California, USA). It has a fixed spot size of 10 mm and gives six stacked pulses at duration of 50 ms.
2. ***1,410-nm System (Fraxel re:fine):*** This has the facility of a variable spot size and a continuous motion scanner, which enables MTZs of 500 μm in depth.
3. ***1,440-nm Nd:YAG Laser (Affirm, Cynosure, Westford, Massachusetts, USA):*** This uses a microarray of lenses and delivers a 10-mm fractional beam. It also has a spot size of 15 mm (470 microbeams), with a microbeam density of 320 spots per cm^2.
4. ***1,450-nm Diode Laser:*** It provides four stacked pulses (210 ms), interspersed with five cryogen applications to ensure cooling. The 4- or 6-mm spot size provides fluences ranging from 9 J/cm^2 to 14 J/cm^2. The usage of energies above 12 mJ/cm^2 has been reported to lead to an increased production of collagen type III but not collagen type I or elastic fibers (Smoothbeam, Candela, Wayland, Massachusetts, USA). The lower penetration wavelength is especially suitable for patients with thinner skin (400 μm with 1,320 nm vs 200 μm with 1,450 nm).
5. ***1,540-nm Er: Glass Laser (Lux1540, Palomar Medical Technologies, Inc.):*** This is a laser that has been widely used by us and can be used in a normal or single pulse mode. The pulses are delivered with a frequency of up to 3 Hz. The system is equipped with a 4-mm spot size to apply typical fluences of 8–10 J/cm^2 up to 70 mJ throughout a chilled sapphire window. It has two tip size 15 mm for superficial indications like melasma and a 10 mm tip used for deeper pathologies like acne scars (Fig. 4.4).

Fig. 4.4: The Star Lux -500 laser system with a Lux 1,540 nm fractional 10 mm handpiece. *Source:* Palomar Medical Technologies, Burlington, MA.

6. ***1,550-nm Erbium Laser (Fraxel, Reliant Technology):*** This was the first device to adopt the concept of fractional photothermolysis. This has been improved upon by the 1,550 nm Er: Glass laser (Mosaic, Lutronic Corporation, Gyeonggi, Korea), which has a large energy range up to 120 mJ. In addition, the system allows for the application of the laser energy in different modes. The so-called static mode, also known as stamp mode, delivers, with the appropriate tips, light to treatment areas of varying sizes (6 × 6, 8 × 8, 5 × 10, and 10 × 10 mm). The system has the advantage of using nonlinear, nonsequential microbeam delivery technology (Controlled Chaos Technology). In combination with variable microbeam delivery and a skin sensing feature within the tips, a decrease of the likelihood of postinflammatory hyperpigmentation in darker skin types is reported (Laubach et al.)

   More recently, a CO_2 laser equipped with a scanner has been used for nonablative fractional treatments. In this, a spot density of 8 × 8 spots/cm^2 (64 MTZ/cm^2) was used. The spot size was set to 500 μm, laser power adjusted to 12 W, and pulse duration set to 3–5 ms (36–60 mJ). On histology slides, the microthermal treatment zone was characterized mainly by absence of ablation and display of very superficial epidermal coagulation immediately after exposure, leading to average increases in skin density of 40.2% without any signs of postinflammatory hyperpigmentation.

Ablative Fractional Resurfacing

There are two types of ablative fractional resurfacing (AFR), the Fractional Er: YAG (2,940 nm), which utilizes traditional ablative wavelengths, such as 2,940-nm (Dermablate, Profractional 2940 laser, Lux 2940, Pixel 2940 Laser and Protocadmus) (Figs. 4.5 and 4.6) and the fractional CO_2 (10,600 nm), which utilizes the standard CO_2 wavelength (Active FX, Fraxel Repair, mixTo, Protocadmus) (Figs. 4.7 and 4.8). The Er: yttrium-scandium-gallium-garnet (YSSG) (2,790 nm) laser is also used for AFR, though the experience with that system is limited (Table 4.3).

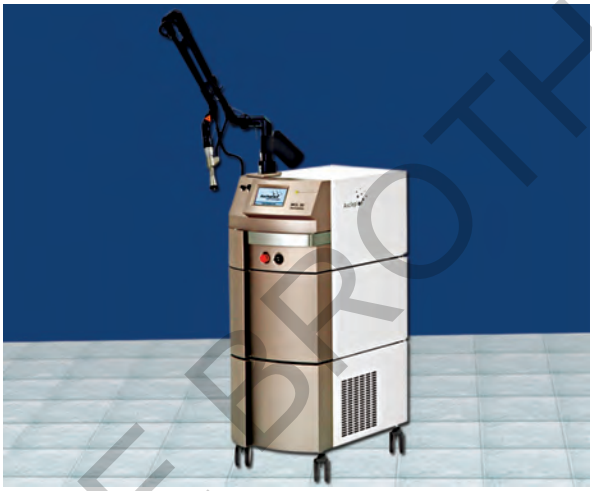

Fig. 4.5: Dermablate (Fractional Er: YAG).
Source: Asclepion Laser Technologies, GmbH.

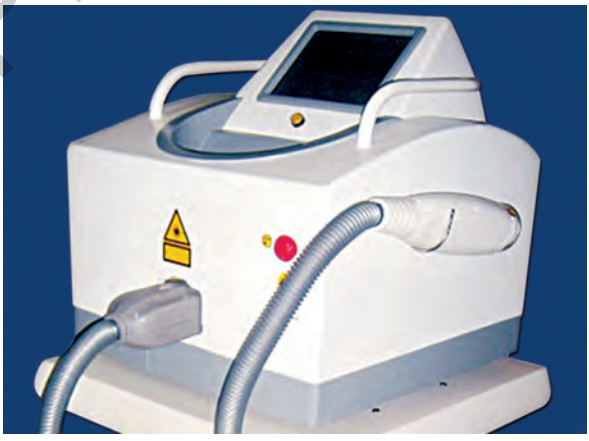

Fig. 4.6: Protocadamus laser system.

Fig. 4.7: SuperPulse CO_2.
Source: Lumenis.

Fig. 4.8: UltraPulse CO_2.
Source: Lumenis.

The rationale for ablative fractional devices is to reduce the number of treatments as compared with nonablative fractional devices and still maintains greater safety than traditional ablative modalities. The depth of the MTZ is primarily dependent on pulse energy and may extend into the deep reticular dermis. The resulting tapered cavity is lined by a thin layer of eschar and surrounded by a cuff of thermal denaturation, which is sufficient to destroy cells and coagulate collagen. Ablative FP results in immediate tissue loss due to the physical removal of portions of the skin by vaporization, and the physical integrity and barrier function of the skin is locally compromised (Fig. 4.2B).

LASERS & ENERGY DEVICES in Aesthetic Dermatology Practice

Salient Features

- A handy book with a focus on existing conventional and novel lasers and energy devices with an accent on patients of skin of color.
- Has three sections—the first covering the technology, the second covering the applications, and the last covering the practical aspects.
- Has leading contributors who are experts in their field.
- Gives frank, unbiased literature overview and practical tips.
- Has a dedicated ***Listed Therapeutic Indications index*** for the busy practitioner.
- Lists elaborate non-cosmetic therapies of common dermatoses.

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