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Laser Versus Intense Pulsed Light: Competing Technologies in Dermatology

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Lasers have been competing with non-laser intense pulsed light (IPL) sources in the cosmetic arena over the past 10 years. Initially IPLs were somewhat cumbersome and accepted by a minority of "serious" practitioners. Recently, however, the popularity of full-face visible light skin rejuvenation, enhanced engineering of IPLs, and favorable cost versus many lasers, have lead to a proliferation of IPL devices. No longer a stepchild in the rejuvenation market, IPLs may overtake lasers as the devices of choice among most physicians. We review the pros and cons of lasers and IPLs within the context of design, cost, and other practical concerns for a typical office-based practice. Lasers Surg. Med. 38:261–272, 2006. © 2006 Wiley-Liss, Inc.

Key words: laser; intense pulsed light; skin; technology; rejuvenation

INTRODUCTION

Intense pulsed light (IPL) sources are quickly gaining acceptance in medical offices and spas. Although initially decried as a poor man's laser and dismissed as having too many side effects and too little efficacy, the newest generation of devices has popularized flashlamps [1–6], and even old guard laser companies have added IPL to their product offerings.

A major reason for the popularity of IPLs is versatility. An IPL can be configured for different emission spectra by varying filtration, lamp type, or current density. Skin coverage rate in cm^2/second (speed) is also important, and despite the slow repetition rate (0.3–1 Hz), large IPL footprints permit rapid treatment of most anatomic areas [7]. Moreover, the cost to generate a target-equivalent J/cm^2 for laser is higher than for most IPLs. An IPL will cost less than a "set" of lasers or a typical combination laser that offers the same range of applications. As IPL technology matures, these "jacks of all trades" are becoming increasingly sophisticated laborers for improving skin conditions amenable to light based therapies. Still, lasers enjoy unique features that enhance their usefulness in specific applications. In this "clinical insight" article, an overview of laser and IPL technology is followed by a brief examination of their respective advantages and disadvantages in clinical practice.

Laser Overview and Laser Advantages

Laser is used in one of two ways—first as a convenient highly concentrated source of photons, and second as a highly coherent light source. The repeatability of laser output from pulse to pulse (the same wavelength is emitted regardless of pumping intensity) is a key laser asset. The other special qualities of lasers that make them useful for medical applications include high *spatial* coherence, low divergence (collimation), and the large number of photons emitted per unit target-surface area (a.k.a. brightness). These inherent properties permit laser beams to be focused and manipulated through articulated arms and fibers at high peak powers. As Rox Anderson MD has stated, lasers are useful because they can achieve exquisite control of where and how much one heats the skin [8].

A laser beam coupled into a fiber or articulating arm can be delivered to a spot distant from the light source. It follows that a typical laser handpiece can be small and lightweight. In contrast, with IPL, the operator's hand must support the lamps, lamp cooling apparatus, and high voltage wires, all in a bulky handpiece tethered to a power supply by a thick sometimes-stiff "umbilical cord" (Fig. 1).

Unlike most IPLs, many lasers check the integrity of the entire system by having the operator place the laser tip into a calibration port. It follows that the same tissue response can be predicted for the same device for like-parameters for each treatment.

Despite criticism leveled against lasers for lack of versatility, combined wavelength lasers are emerging, and systems such as 1064 and 595 nm (Synergy, Cynosure, Chelmsford, MA), and 532 and 1064 nm (Gemini, Laserscope, San Jose, CA) are now in clinical use. One miniature combination laser (VariLite—532 and 940 nm, Iridex, Mountain View, CA) allows for sequential treatment of superficial and deeper vascular lesions (Fig. 2).

Like IPLs, lasers are becoming smaller, more efficient, more powerful, and less expensive. Higher peak powers, larger spots, increasing repetition rates, and novel accessories are enhancing their usefulness in skin rejuvenation. By manipulating pulse duration, spot size, and cooling, single wavelength devices can be used for multiple clinical

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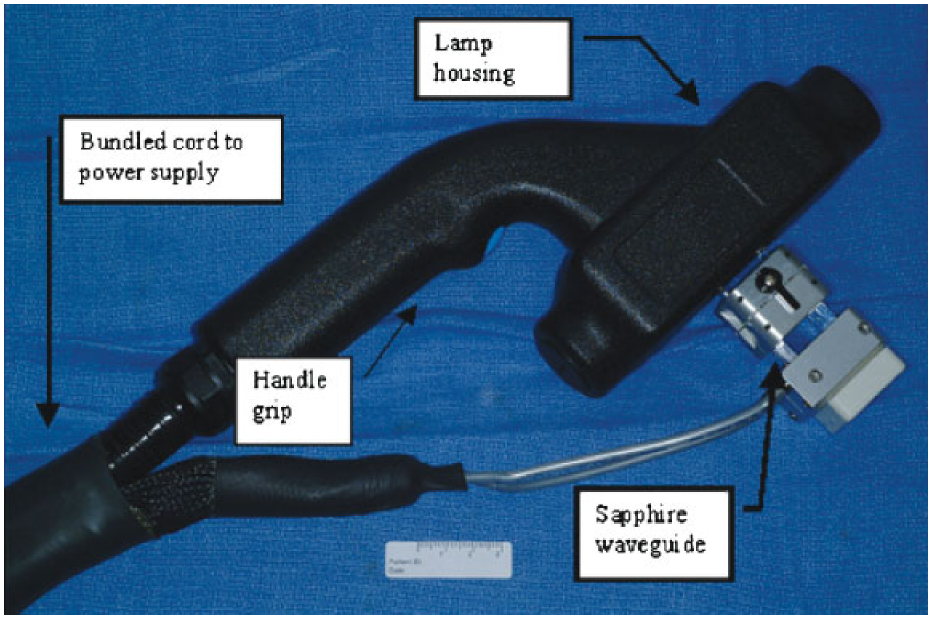

Fig. 1. A representative IPL handpiece. Note the caliber of the proximal cord and the overall size of the handpiece.

indications. For example, a newly introduced pulsed dye laser (Aesthetica, Candela Corporation, Wayland, MA), depending on a user-selectable cooling and handpiece configuration, can be optimized for pigment or vessel heating, respectively [9]. Thus, old wavelengths can be "taught" new tricks.

Newer platforms such as Fraxel (Reliant, Palo Alto, CA), which incorporate novel scanning technology to create a pattern of microwounds in the skin, highlight the laser's ability to morph for pioneering applications [10].

Most lasers (the exception being diode arrays where the laser bars are in the handpiece tip) provide excellent real-time visibility of the skin surface. The direct visualization of clinical endpoints facilitates optimal treatment of blood vessels, hair, and pigmented lesions.

Laser Disadvantages

Some solid-state lasers operate best on 220 V (i.e., alexandrite, ruby, and neodymium YAG), such that exam rooms must be designed to accommodate this requirement. Also, because of their inefficiency, some lasers generate significant heat in the exam room. Wavelength-specific optical components tend to be expensive, and compared to IPL, the optical configuration inside a typical laser tends to be more intricate and "breakable." Many lasers are particularly vulnerable to "jarring" movements.

Although diode lasers are becoming smaller and less expensive, diode arrays are necessary to deliver high peak powers, and like their IPL counterparts, position the "light source" in a sometimes-unwieldy handpiece that resembles a typical IPL handpiece.

The collimated nature of laser light makes it less eye-safe than IPLs, and both patient and physician are vulnerable to the larger nominal hazard zones.

IPL Overview and Advantages

At the site of absorption, the coherence properties of laser are not important for therapeutic skin applications. Also, biological reactions are not intrinsically specific to the heating source. In principle, a large number of non-laser devices (e.g., radiofrequency or microwaves) could be used for heating skin [11]. Although monochromaticity is a key feature of laser light, the three main chromophores (hemoglobin, water, and melanin) in human skin all have broad absorption peaks. Also, protoporphyrin IX (from aminolevulinic acid) can be excited by polychromic IPL, as the major absorption bands include 410, 504, 538, 576, and 630 nm. It follows that monochromaticity is not a prerequisite for selective heating, and for many dermatology applications requiring millisecond (ms) or longer pulse deliveries to large skin areas, IPLs are either adequate or even preferable to lasers [12].

IPLs use flashlamps, computer-controlled power supplies, and bandpass filters to generate light pulses of prescribed duration, intensity, and spectral distribution. The laser is really a fancy way to convert polychromic lamp to monochromatic light [12]. Rather than using a xenon flashlamp to pump a laser, IPLs "bypass" this step and use the lamp directly (akin to a slide projector that emits white light, which is converted to a narrower range of colors by an external "filter"). Flash lamps are gas-discharge lamps of high intensity filled with xenon gas that produce bright light when an electrical current passes through the gas. These lamps work in a pulsed mode and convert electrical energy stored in capacitor banks into optical energy covering the spectrum of light from ultraviolet (UV) through the infrared. Most modern IPL systems use partial discharge technology to ensure an even flow of energy [4].

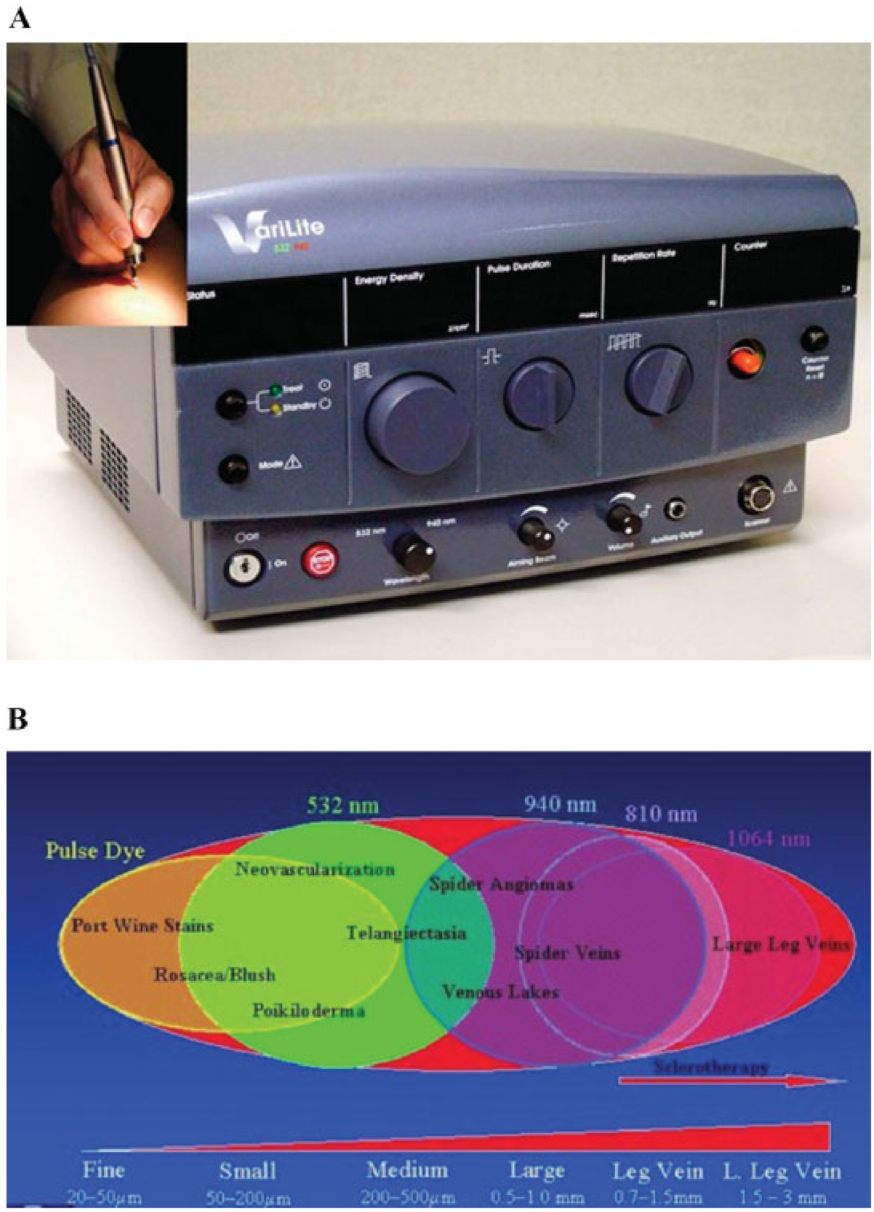

Fig. 2. **A**: Note small size of this versatile combination laser with ergonomically friendly handpiece (inset). **B**: Diagram showing how only two wavelengths with this device (532 and 940 nm) can span range of vascular applications (without the need for broader range of wavelengths available with IPL).

The flashlamp includes mirrors surrounding the xenon or other lamp source. The lamp is cooled by water circulating around a quartz envelope. The envelope filters out most of the harmful far-UV output of the lamp. The lamp output is directed toward the distal end of the handpiece and is usually coupled into the skin surface via a sapphire or quartz block. Although most IPLs use a single lamp, some IPLs use multiple flashlamps to eliminate a tendency for hotspots in the beam profile that might be observed at the skin surface.

Engineers have improved IPL power supplies, optical components, and accessories [13]. The result is enhanced reliability, increased predictability of the skin response, and a wider range of clinical applications [14]. The normal, unfiltered output of a xenon lamp is between 370 and 1800 nm. Most IPLs use dichroic filters to transmit a range of wavelengths. These filters are composed of stacks of dielectric materials wedged between quarter wave plates [15]. Depending on the dielectric thickness, certain wavelengths of light are reflected back toward the lamp. Because of variations in reflection based on angle of incidence, the range of transmitted colors can vary with the same filter. Off-angle incident light will be of shorter wavelengths than light incident perpendicular to the filter surface. For example, a typical 560 nm dichroic filter permits 10–15% of light <560 nm to pass through the filter. Figure 3A illustrates an actual spectrum for a representative dichroic "cut-off" filter. The blue light (Fig. 3B) that "leaks" through the filter can cause epidermal damage, particularly in the absence of cooling. However, more important than transmitted blue light is the familiarity of the operator with a particular device. If one has considerable experience with any IPL, regardless of the subtleties of the spectral signature, one should be able to apply treatment settings that are safe and effective for particular clinical indications. To enhance patient safety, most modern "high-end" IPLs actively cool the skin surface. For a particular IPL system, either cryogen spray, forced refrigerated air, or contact cooling may be integrated into the distal end of the handpiece.

Most dichroic filters use a "slide-in" or "snap-on" approach (Fig. 4). Some IPLs use both absorption and dichroic filtration [2]. In this manner "dual-band" handpieces can be created (Fig. 5). Thus, for example, for the LuxG handpiece (Palomar Starlux, Burlington, MA), blue light is absorbed, while the majority of the wavelength range between 650 and 870 nm is reflected back into the handpiece. This combination filter design provides extra protection for the skin. If a device uses absorption filters, they must be actively cooled by circulating water.

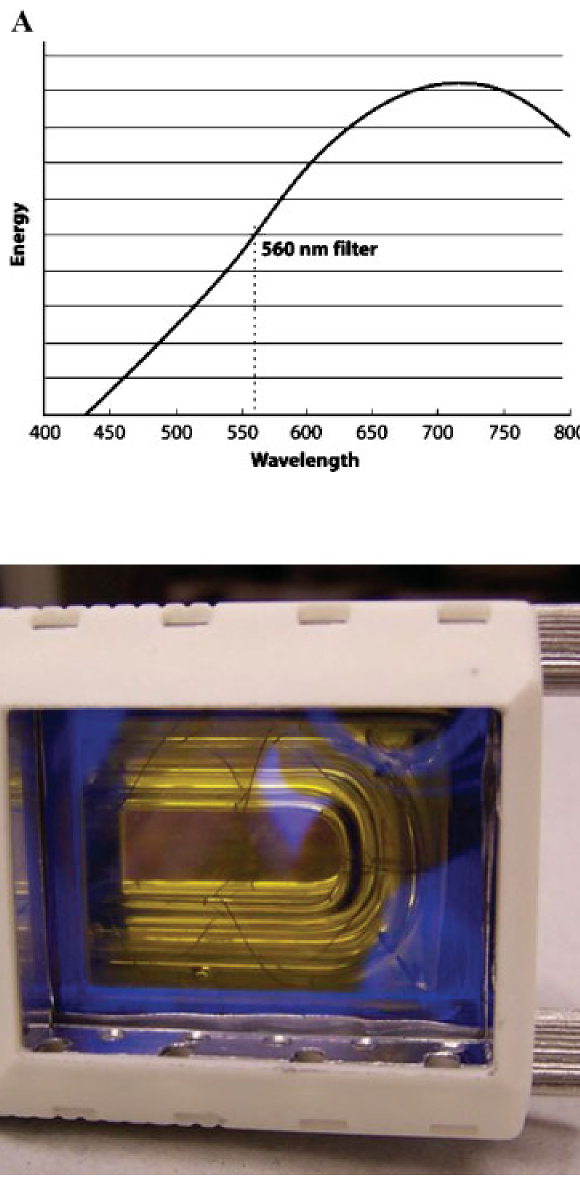

Fig. 3. **A**: Filter output of typical dichroic configuration. **B**: An example of a "yellow" dichroic filter showing blue light "leakage" from the sides of the handpiece.

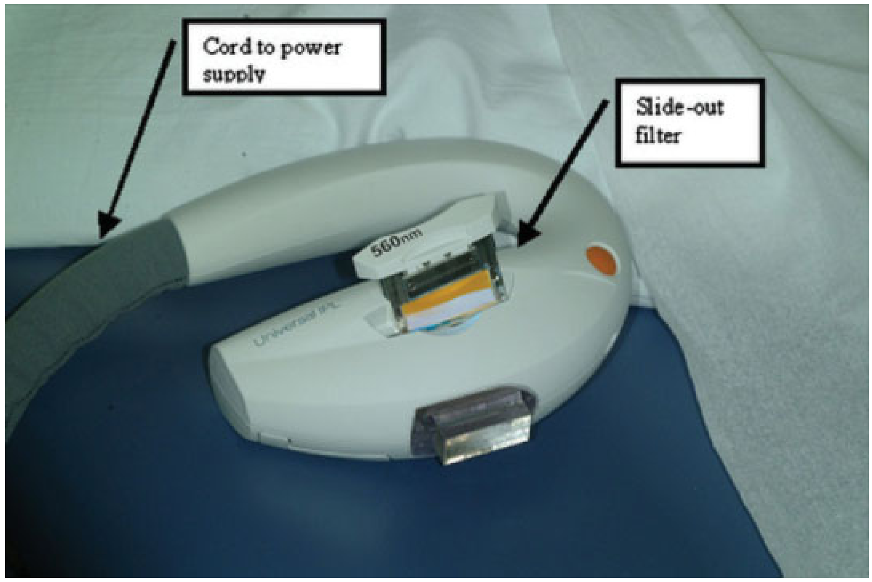

Fig. 4. "Slide-in" dichroic filter for Lumenis ONE handpiece (Lumenis, Yokneam, Israel).

Otherwise the filter will crack in a very short time. This cooling requirement requires that an IPL with absorption filters use separate "whole" handpieces for different output spectral ranges.

One IPL (Omnilight, American Medicalbiocare, Newport, CA) uses fluorescent polymers (Fig. 6A,B) to convert the shorter and most harmful wavelengths to more beneficial visible light. One advantage of fluorescent dyes is that one can reduce the lamp voltage (thereby increasing the life of the lamp) and still create a high output in the desirable portion of the spectrum. About 30–50% of the short wavelength (unusable) light is converted through fluorescence. Another portion of the light is directed back toward the lamp. The remainder of the energy is transmitted through or absorbed by the polymer wafer. The latter results in heating of the wafer, which can only endure about 100 pulses before degrading.

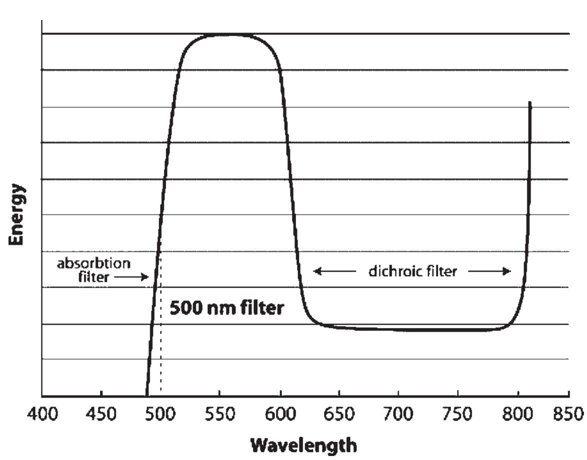

Fig. 5. Graph shows output from dual filtration (dichroic plus absorption filter).

One generational improvement in IPLs is the replacement of quartz with sapphire. Although quartz is almost as durable and much cheaper, sapphire has a much higher thermal conductivity and thermal diffusivity than quartz. The result is that sapphire and skin brought into contact will show an immediate surface temperature of 12°C (skin initially at 32°C), whereas quartz will show an immediate contact temperature of 18°C (assuming the temperature of the sapphire or quartz are both at 10°C) [16,17]. The end result is improved epidermal protection and the potential use of higher light doses in hair removal and vessel closure. One IPL (Solis, Laserscope, San Jose, CA) uses cryogen spray cooling (CSC) in a design where the lamp resides 1 cm above the skin surface, and the spray emerges through multiple ports along the perimeter of the plastic enclosure (Fig. 7). Light losses are mitigated by reflectors placed throughout the interior of the handpiece housing.

Reproducibility of skin tissue effects from pulse to pulse has improved among newer generation IPLs. For example, in early versions of IPLs without integrated cooling, one was instructed to maintain a thick layer of gel between the quartz crystal and the skin to keep the surface cool (after multiple pulses, an "uncooled" quartz crystal will tend to warm). However, because of the rapid beam divergence of IPL, even a few millimeters distance between the handpiece and the skin surface affects the fluence. Thus, surface fluences were vary dependent on the pressure between exerted by the operator-firmer pressure resulted in a higher fluence and more robust tissue effects. With the addition of active cooling and/or sapphire, close concert between the skin and handpiece results in more repeatable dosimetry.

A

B

480 (Filter)	Performs the role of...	Argon Laser without its maintenance issues
515	Performs the role of...	Copper Vapor Laser
535	Performs the role of...	KPT Laser & 532 mn Diode Laser
550	Performs the role of...	585 Pulse Dye Laser
580	Performs the role of...	585 Pulse Dye Laser
615	Performs the role of...	Ruby alexasndrite 810 mn Diode & Nd:YAG Lasers

Fig. 6. **A**: The array of available fluorescent "cut-off" filters. **B**: Note table showing "laser" equivalents for each polymer fluorescent wafer.

One IPL (Prowave, Cutera, Burlingame, CA) uses varying current density to create different emission spectra (Fig. 8). Along with the spectral change, the device configuration for treatment of darker skin includes a lower sapphire tip temperature and longer pulse. All these changes are accomplished electronically, so that one can change the output by simply pushing a button on the instrument panel rather than having to take the time to exchange handpieces and/or a filter assembly.

The beam divergence of IPLs makes them more intrinsically eye-safe than lasers. On the other hand, many operators are unjustifiably dismissive of the damage potential of the lamp filament, and many physicians shun goggles with IPL, particularly the dark neutral filter types, because the operator's vision is obscured [18]. However, patient eye injuries have been reported after IPL treatment, and eye protection is recommended for both operator and patient [19]. A newly introduced goggle (Lightspeed, Glendale, Smithfield, RI) that darkens only on light exposure has increased the acceptance of wearing eye protection with IPLs.

IPL Disadvantages

There are some drawbacks with IPL. Because such devices do not enjoy the monochromaticity of an optically pumped laser rod, even with the same filter configuration, the spectrum may not be consistent from pulse to pulse (or during the pulse). IPLs are vulnerable to the instantaneous "pumping" voltage of the capacitors. It follows that during the course of a pulse, the spectrum changes as the power ramps up and down. In a typical configuration, the beginning and end portions of the pulse are red shifted (less energetic) and the middle of the pulse will be blue-shifted (Fig. 9). Most modern systems use a sophisticated computer control system that minimizes this so-called spectral jitter.

One complaint about IPLs is the lack of maneuverability of their typically large handpieces and large spot sizes over irregular skin surfaces. Also, discrete lesion treatment is not facilitated. A user-selectable spot size could obviate some of these problems. However, although intuitively attractive, manufacturers cannot just "focus" an IPL to achieve higher intensities, because with non-laser sources, it is physically impossible for the light intensity at the skin surface to exceed that delivered by the source lamp. Despite these theoretical limitations, by using a long cylindrical sapphire waveguide and high performance reflectors, one manufacturer has developed a "small" 6 mm spot IPL source (Acutip, Cutera, Burlingame, CA) for treatment of discrete brown and red dyschromias (Fig. 10).

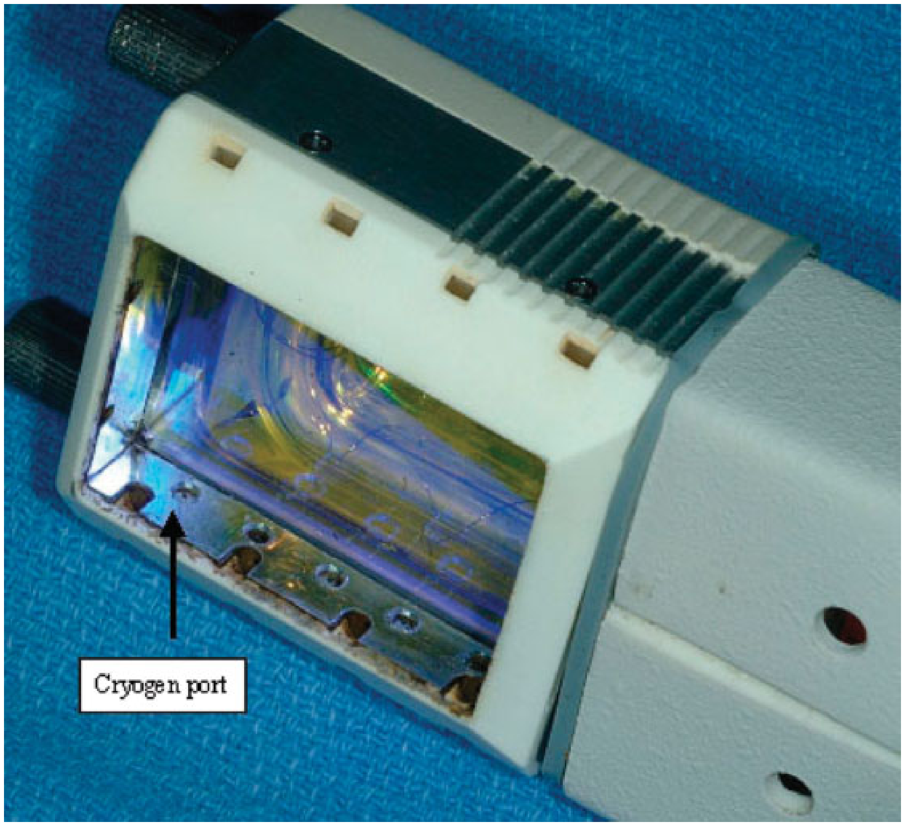

Fig. 7. IPL handpiece that uses cryogen spray cooling.

With IPLs, exchanging treatment settings between various manufacturers and devices (or even successive similar models by the same manufacturer) can be perilous, as the effective fluences may not be equivalent. Changes in lamp pumping affect the pulse profile and spectral emission, so that simple changes in fluence can impact another treatment parameter (a domino effect). Also, despite nominally identical spectral filtration, various devices emit different wavelength ranges and spectral shapes. It follows that with the same macropulse duration, nominal filtration,

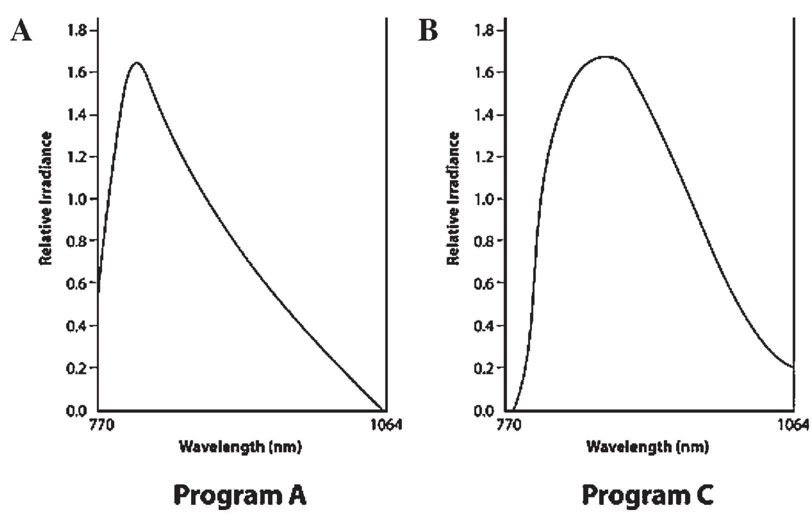

Fig. 8. **A** and **B**: Spectral emission from same filter with two programs—A shows “A” program where spectrum is optimized for lighter skin and lighter hair B. Program “C” decreases current density to the lamp and therefore “red shifts” the spectrum.

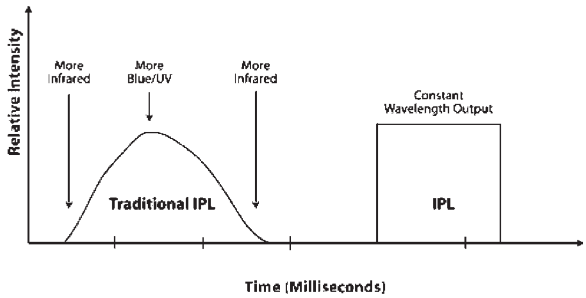

Fig. 9. Graph shows temporal changes in spectral output as a function of instantaneous power to lamps. First pulse profile shows effect of varying instantaneous power. Second shows uniform power across entire pulse that results in uniform spectral output throughout pulse.

and fluence, light can penetrate to different depths and exhibit different absorption by human skin.

Characterizing the skin response to IPL is more complex than for laser radiation. Without viewing the actual spectrum, predicting fluence-specific skin responses is difficult. Algorithm tables that prescribe application-specific fluences and pulse durations are only meaningful if provided within the context of an individual model and manufacturer.

Companies may use different techniques for measuring IPL fluences at their manufacturing facilities. Some companies optically couple energy into the calibration head of an energy meter to give the "effective fluence" to tissue. Thus, the fluence on the instrument panel might not represent the energy density at the end of the sapphire or quartz tip. Some IPLs do not include an external calibration port so that real-time lamp degradation may not be accounted for over the lamp lifetime.

Because of the broad-spectrum nature of most IPLs, there is a risk of hair reduction in male patients during skin rejuvenation. For example, even most green–yellow IPL emission spectra emit significant light beyond 600 nm, some of which penetrates deep enough to cause hair reduction. Hair reduction for several months can be observed after treatment, even with some so-called "shallow light penetration" IPL handpieces.

Because of rapid IPL beam divergence, the handpiece normally must be in contact (or almost in contact) with the skin for effective treatment. Therefore, the physician cannot observe immediate local responses to IPL exposure. Depending on the IPL design, treatment over firmer surfaces (i.e., dorsum of the nose) can result in vessel compression and ineffective treatment of telangiectasias (Fig. 11A,B).

Larger IPL spot sizes, while ideal for covering large areas, also pose the risk of "large" side effects. The larger spots also make it difficult to work in tight concave areas (i.e., nasal ala crease). One manufacturer has created a masking blocker (Fig. 12) to localize the heating effect, but its precise placement can prove cumbersome. Although some operators contend that IPLs are safer than lasers, complications are not uncommon [20,21].

Some wavelength ranges are not possible with available IPLs. For example, there is no commercially viable FIR wavelength system similar to CO_2 and/or erbium YAG that would be useful for LSR.

Direct Comparisons

There are few direct comparison studies between non-laser and laser light sources. In some studies, port wine

Fig. 10. Novel 6 mm spot "KTP"-equivalent IPL.

A

B

Fig. 11. **A**: Picture of IPL shows how larger footprint of device is not ideal for concave nasal crease. **B**: KTP laser shows how user can visualize endpoints just before and after treatment in an ergonomically friendly handpiece.

stains (PWS) were treated with IPLs after PDL failed to achieve additional benefit. In these studies, most often the PWS continued to improve [22]. Raulin [23] noted that in treatment of resistant PWS, IPL's broad spectrum might allow for the exploitation of the full breadth of hemoglobin absorption peaks, from 540 to 940 nm, allowing for potential destruction of both deeper and superficial components of the lesion. However, there are no controlled studies where one takes an untreated PWS and divides it into IPL and laser treated areas. A small study suggested that IPL and PDL were statistically equivalent in treatment of hypertrophic scars; however, the PDL did overall perform better (80% mean improvement vs. 65% after two treatments—no control was noted) [24]. At least one study comparing laser and non-laser sources in hair removal showed equivalent results after several treatments [25]. A recent study compared IPL and KTP lasers in a side-by-side comparison of reduction of brown and red dyschromias [26]. Both sides achieved similar improvement in epidermal pigmented and vascular lesions. To make the study fair, both devices were used with fluences just below the threshold for epidermal damage. Also, the investigators were experienced with both devices [26].

Combination Devices and the Future

"Hybrid" devices such as the Xeo system (Cutera, Burlingame, CA) and Sciton BBL (erbium YAG plus IPL) use platforms that support modular bays of lasers and IPLs. A physician can therefore purchase a base system and add accessory handpieces and/or laser rods that are "custom" fitted to the needs of the practice (much like upgrading a desktop computer).

Also, IPL platforms are being used to pump small laser rods as a standalone handpiece (Fig. 13). Thus, the debate over IPL versus lasers may become confounded as the distinction between pure laser and non-laser platforms becomes progressively blurred.

Light emitting diodes (LEDs) are another light source that will be used more in the future. LEDs already are used extensively in photodynamic applications. Other lamp sources are being used in addition to xenon such as tungsten–halogen, which generates wavelengths in the mid-IR range that permit heating of dermal water.

One company (Aesthera, Pleasanton, CA) has coupled a suction device into an IPL platform to move the skin targets closer to the surface. Suction stretches the skin, decreasing the melanin density per unit area and bringing dermal targets, such as telangiectasias and the hair bulb, closer to the skin surface. These manipulations allow the use of shorter wavelength, more energetic photons in skin applications.

Some IPLs and lasers incorporate radiofrequency energy into their designs. In a typical configuration, cooled metal rails are located at the edges of the sapphire window. The rails invest RF energy into the skin in a bipolar design where purportedly there is synergy between the optical and RF components. Models show enhancement of heating of subdermal targets (vessels and hair) with equivalent

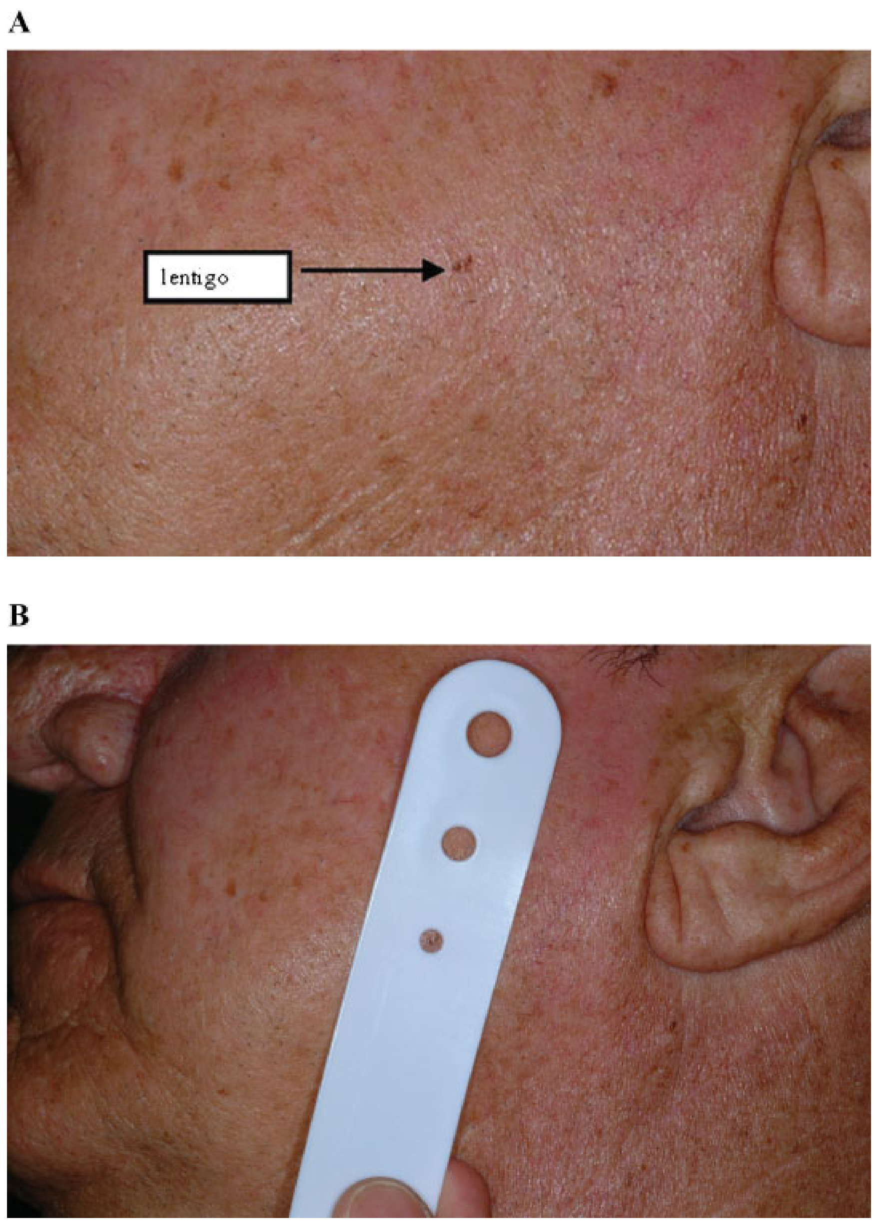

Fig. 12. Plastic opaque masking device that converts large IPL footprint into smaller one. Note how accessory allows for discrete lesion treatment. **A**: Lentigo before treatment, **B**: with mask in place just prior to irradiation, **C**: IPL pulse being delivered.

C

Fig. 12. (*Continued*)

optical fluences, and multiple studies support these devices in skin applications [27–31]. However, no peer-reviewed study has compared their efficacy with and without the RF component; it follows that the actual clinical role of RF in this configuration is unclear.

DISCUSSION

After consideration of the advantages and drawbacks of IPL and lasers, an algorithm for their optimal use can be developed. Because both lasers and IPL devices have improved, there is substantial overlap in applications; and for the vast majority of patient presentations, depending on the device-specific experience of the operator, lasers and IPLs are interchangeable. For example, lasers and IPL devices both work quite well for hair removal.

There are applications where lasers are optimal, for example, where real-time visualization of the target is essential. Also, when using visible light for rejuvenation

Fig. 13. Nd:YAG handpiece extending off IPL platform; handpiece houses rod and lamps.

(especially vessel reduction) in darker skinned patients, lasers permit a level of control that is the essential where there is a small window between effective and safe fluences. Another laser-preferred venue is where maneuverability is essential, for example around the nasal crease and/or the orbit. Q-switched lasers are essential where ultrashort (ns) pulses optimize treatment of tattoos and nevus of Ota [26]. Also, newer intravenous techniques for vein ablation require laser light for coupling into the fiber [32].

Otherwise, the decision to use an IPL or laser is oftentimes determined by the physician's bias and familiarity with a specific device. At other times the choice is based solely on office efficiency, and whatever device "happens to be in the room" is used to expedite patient care. This interchangeability between devices reduces the "musical chairs" scenario often observed in a "laser" practice.

Undoubtedly, room exists in the cosmetic arena for both laser and non-laser sources. IPLs might gain a greater foothold in the future, but any predictions for the demise of laser are premature. Engineering advances will ultimately determine the respective roles of IPLs and lasers in skin rejuvenation.

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