White Paper

VIAVI Solutions

Optical Technologies for Aesthetic Laser Applications

Aesthetic Lasers, also known as medical aesthetics or aesthetic laser treatments, refers to a range of medical procedures that use light-based technology to improve an individual's appearance. Treatments include fat reduction, wrinkle reduction, laser hair removal, and tattoo removal.

Low Level Light Therapy (LLLT) is differentiated from Laser Aesthetics by both the light-tissue mechanism of action and the application spaces they target. Some LLLT applications include treatments for acne, herpes, skin rejuvenation, pigmentation, and vitiligo. Most LLLT applications relate to pain relief, healing, inflammation reduction along with other therapeutic (vs. aesthetic benefits).

This white paper provides a brief introduction to aesthetic laser technology and the benefits of VIAVI Light Shaping Optics and Thin Film Optical Coatings in devices for aesthetic treatments.

Market Environment

The global aesthetic cosmetic lasers market is estimated to generate more than $1B in revenue annually according to VIAVI's internal analysis. Major market drivers for aesthetic lasers include a growing consumer preference for non-invasive cosmetic procedures that can be performed outside a hospital setting, an aging population brought up in a culture that celebrates youth, and increasing disposable income available for discretionary medical procedures.

Non- and Minimally- Invasive Procedures. Demand for non-invasive and minimally invasive laser based aesthetic procedures is growing, enabled, in part to advances in technology. Innovative technologies offer alternatives to surgically invasive treatments interventions, attracting individuals seeking aesthetic enhancements with low downtime and moderate risks. Recent advancements in laser technology contribute to improved precision, spectral flexibility, safety, and efficacy while enabling the expansion of the range of available applications.

Aging Population. The global aging population and a growing focus on maintaining a youthful appearance – particularly among the Baby Boomer generation ages 60 to 78 as of 2024 who are amongst the affluent consumers - have increased the demand for aesthetic procedures and laser treatments, including skin rejuvenation and wrinkle reduction. With millennials entering their 40's, the demand for non-invasive aesthetic treatments is also on the rise. Social media platforms like Instagram and evolving beauty standards have placed a greater focus on personal aesthetics and appearance. This shift driven by social media as well as cultural acceptance has led to a surge in demand for cosmetic procedures.

Increasing Disposable Income. Increasing disposable income levels in various geographical regions enable more individuals to afford aesthetic procedures. While disposable income is on the rise globally, the rate of disposable income growth is higher in the emerging and developing countries, coinciding with higher growth of aesthetic laser-based treatments.

Aesthetic Laser Procedures

Aesthetic Laser devices generate specific wavelengths of light that interact with the skin's tissues, allowing for a range of treatments and procedures. In most procedures, the energy from the illumination light is absorbed by specific components in the skin, such as pigments, blood vessels, or hair follicles to provide desirable outcomes with minimal invasiveness (in contrast to traditional surgical techniques).

The working principle in laser-based aesthetics is demonstrated in the following figure representing a hair removal treatment. In this example, either a monochromatic laser beam or a broad light source such as IPL (intense pulse light) beam is used to destroy the hair follicle or the root of hair – preventing future growth of hair.

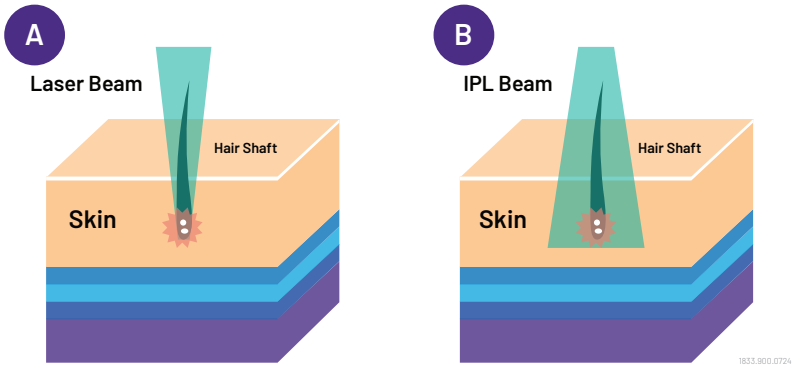


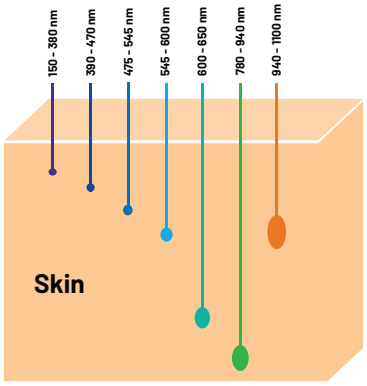
Figure 1

Laser treatments can generally provide effective results with less downtime, fewer risks, and minimal scarring compared to invasive surgical procedures. However, given the diversity of skin types in human population and complexity of interactions between light and biological tissues, the full impact and benefits of various aesthetic laser treatments are still being understood. The ability to provide effective and personalized treatment with minimal side effects is a primary goal of practitioners and presents an opportunity for continued development of instruments and applications in the future.

Types of Light Sources in Aesthetics

Low Level Light Therapy (LLLT) utilizes either lasers or broadband light sources. Lasers, which emit monochromatic and coherent light, generate high density energy that can be narrowly focused to penetrate deep into the tissue. A key benefit of that focus is that laser-based devices can be precisely targeted to specific types of skin or toward precise treatment outcomes.

Figure 2 illustrates tissue penetration depth utilizing various laser wavelengths. This table is not an exhaustive list of laser wavelengths. For example, CO^2 lasers with >10 µm wavelength are also used for treatment of acne or skin rejuvenation.



Wavelength (nm)	Color Range	Penetration (mm)
150-380	UV	<0.1
390-470	Violet to Deep Blue	~0.3
475-545	Blue-Green	~0.3-0.5
545-600	Yellow to Orange	~0.5-1.0
600-650	Red	~1.0-2.0
650-950	Deep Red-NIR	2-3
950-1200	NIR	1

Figure 2

Also depending on the application needs, either continuous wave (CW) or pulsed lasers can be used. Compared to CW lasers, pulsed lasers can provide much higher peak power, into very small regions, therefore treatment can be localized without damaging the surrounding skin, such as in birthmark removal.

In contrast, intense pulse light (IPL) devices are non-laser based high intensity light sources that make use of a high output flashlamp to produce a broad wavelength output of noncoherent light, usually in the 500 nm to 1200 nm range. The broad wavelength range discharged from an IPL device leads to the simultaneous emission of green, yellow, red, and infrared wavelengths allowing the various chromophores to be targeted concurrently. Use of optical bandpass filters with precise edge placements enables narrower wavelength range for treatment.

IPL based treatments are generally faster and more affordable than laser-based treatments. However, IPL based devices may lack the specificity and longevity of personalized treatments that can be achieved by laser-based treatments. Given the need to tailor a device and treatment to the specific circumstances, clinicians are critical in making appropriate selection of methods for the desired outcomes.

Working Principle of a Laser Aesthetic Instrument

Figure 3 illustrates the working principle of a laser aesthetic instrument. Typically, one or more laser wavelengths of illumination are used to cover the range of treatments.

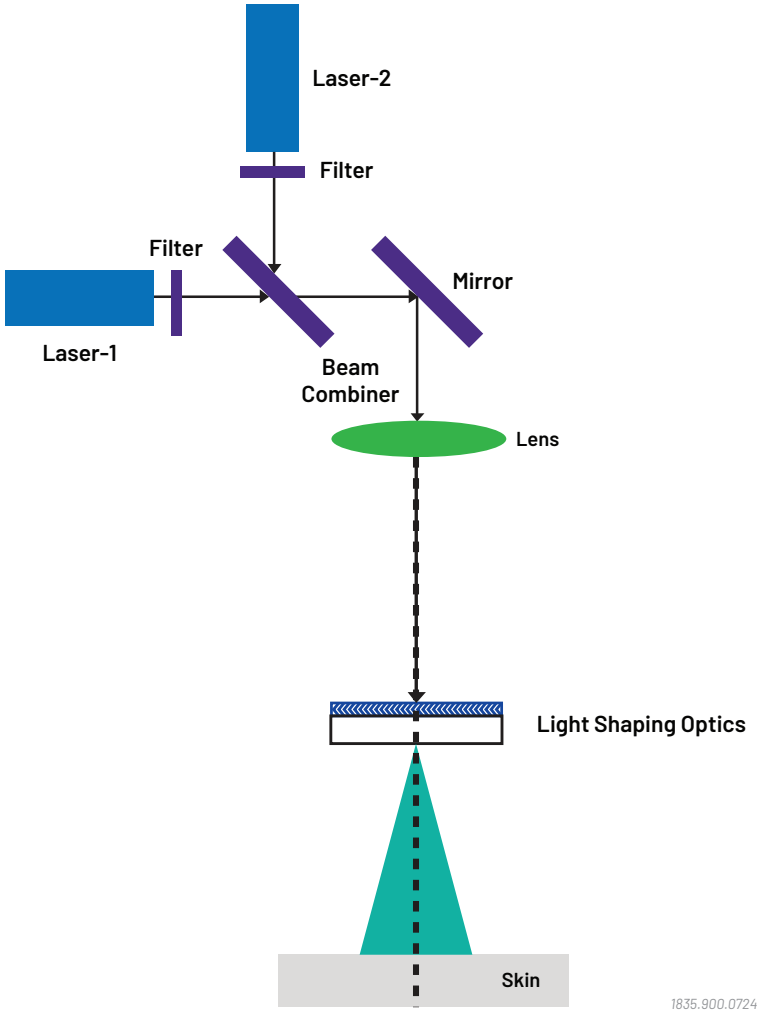


Figure 3

The laser beam pattern on the patient's skin is not only a key requirement in achieving the desired outcomes from the medical procedure, but also very important for patient's experience during the aesthetic procedure. Optics in the laser delivery systems play a critical role in enabling these outcomes.

Illustrative examples of beam pattern shapes generated by Light Shaping Optics are included in Figure 4.

While circular beam patterns are popular, square, rectangular, or linear beam patterns are also used based on application.

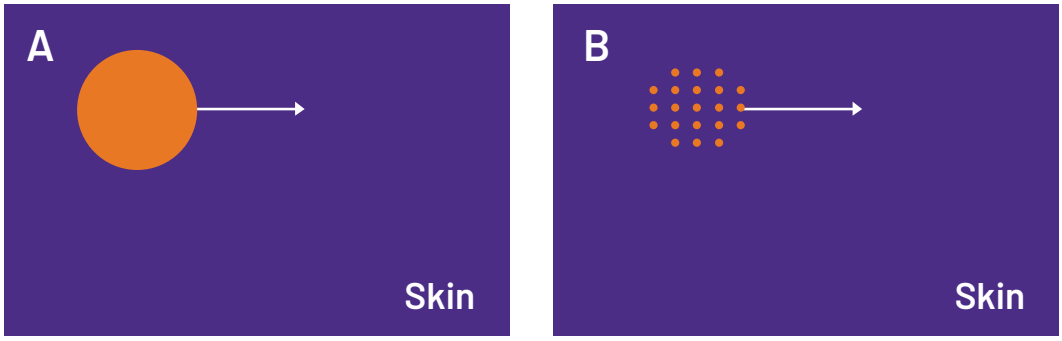


Figure 4

Top-hat beam profile generated by Light Shaping Optics refers to the cross section of the intensity profile on the skin, for example Figure 5, below. From the patient's perspective it is important to achieve effective procedure, in a short period of time while being cost effective. Light shaping optics is a key enabler to achieve these goals by ensuring that the illumination profile mimics ideal Top-hat profile with high contrast illumination spots.

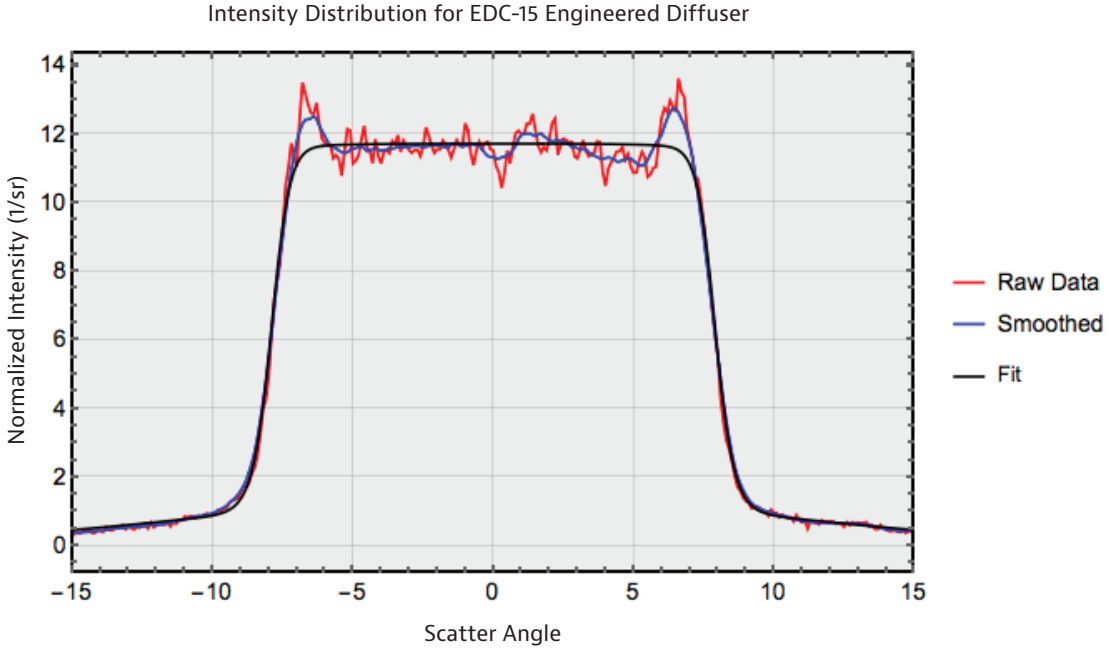


Figure 5

Light Shaping Optics offer predictable laser aesthetic treatment, improved manufacturing yield, and reduced instrument cost with batch-to-batch reproducibility and high precision optical products at scale.

Benefits of Light Shaping Optics in Laser Aesthetics

VIAVI Engineered Diffusers® enable uniform illumination beams with sharp contrast and no zero-order hotspot to enhance customer feel and experience and ensure desired treatment outcomes. Diffusers improve the beam quality and functionality of the raw laser beam by generating a uniform expanded area of illumination. This not only benefits the patients due to faster and predictable treatments, but also enhances the clinics' return on investment for aesthetic laser instruments since a larger number of procedures can be performed in a given time.

VIAVI refractive optics are not only free from zero-order hot spot but maintain performance over large spectral ranges for any input beam profiles and help reduce speckle in laser illumination. These benefits simplify the system level designs reducing complexity and cost.

Our highly robust Reactive Ion Etched Products provide enhanced efficiency of light management in high power illumination instruments and benefits both the instrument manufacturers and the clinics. By running the lasers at reduced power level (due to improved transmission efficiency) the life of the lasers is improved, or a lower cost laser can be used in the system. At the same time, since durable etched products can be used for more procedures, it helps reduce the cost of each treatment.

Polymer on glass products offer lower cost solutions and are well suited for instruments utilizing lower power without compromising the quality of the illumination beam. To minimize risks of infections instrument manufacturers are also considering disposable diffusers that are personalized and unique for everyone. VIAVI's 300 mm diameter wafer level manufacturing for polymer on glass products ensures consistent product performance at a price point of consumer devices.

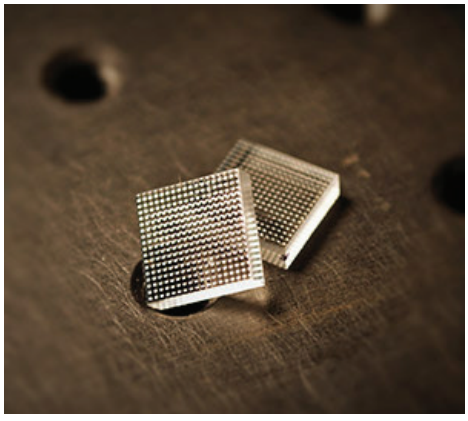
The diffuser is also used to control the maximum spatial intensity in the beam to manage eye safety. Since diffusers spread the light over a larger region, the intensity of light is significantly reduced making the laser beam less hazardous in the clinical setting. Specifically, VIAVI's refractive diffusers minimize any concerns relating to hot spots (central region of the diffuser with higher intensity), thereby further providing peace of mind. In LLLT, it is possible to diffuse the beam to create an effective exposure while still maintaining a large enough beam, so the laser is eye safe.

VIAVI proprietary know-how enables ultra-wide field-of-view (FOV) diffusers for faster body contouring and fat removal treatments. This is a new and emerging area of application — where large regions of the body require uniform illumination beams. Conventional diffusers for higher power lasers are generally made of fused silica glass. Fused-silica based diffusers can achieve ~30° field of view illumination. However, innovative materials with much higher refractive index compared to fused silica, can generate wider field of view illumination, even >100° significantly improving illumination throughput and cost reduction for the instrument manufacturer.

Refractive Light Shaping Optics reduce instrument complexity and cost and enable consistent performance through wavelength agnostic performance over wide spectral range.

Engineered Diffusers can provide a flat spatial profile allowing maximum fluence below the necrosis threshold. In the case of LLLT, it can also control the peak intensity for eye safety. Controlling the spatial beam properties optimizes safety and efficacy. In addition, it can enhance patient feel and experience and enable faster treatment for body contouring and fat removal with uniform beam illumination.

Diffractive Optical Elements (DOE) arrays and **Micro-Lens Arrays** enable consistent illumination in laser aesthetics and improve light throughput leading to reduced instrument cost and reduced needs for reflected stray light management due to high transmission light shaping optics.



Highly robust **Reactive Ion Etched Products** provide enhanced efficiency of light management in high power illumination instruments. Inorganic material types (Fused Si, Silicon, Ge, Thin film coated high refractive index materials) provide light management solutions for a broad range of applications utilizing UV to IR wavelength ranges (180 nm to 12 microns) with minimal transmission loss.

Polymer on glass products offer low-cost solutions in high volume and enable disposable and personalized solutions for users.

- 300 mm wafer level manufacturing
- Up to 0.2 mm thin glass substrate

Benefits of Thin Film Optical Coatings in Laser Aesthetics

VIAVI optical filters provide spectral purity and consistency of illumination beams ensuring desired outcomes in skin rejuvenation treatments. We uniquely combine quality, performance and low- cost solutions in our offerings, while de-risking supply chain with our facilities and teams based in the US and Asia.

Optical Filters provide spectral purity and consistency of illumination beams ensuring desired outcomes in aesthetic laser treatments. Wavelength specificity and spectral purity determines which tissue within the skin will be targeted and heated by illumination wavelength, allowing for selective destruction of unwanted features like melanin (pigmentation) or blood vessels, while minimizing damage to surrounding tissue, achieving the desired aesthetic outcome with maximum safety and efficacy.

Bandpass/Edge Filters, such as VIAVI's narrow bandpass laser line filters, ensure spectral purity of illumination beam improving desired treatment, consistent illumination leading to consistent treatments, and consistent performance leading to reduced cost. Cost reduction is achieved both due to effective utilization of reduced laser power, as well as by ensuring more effective treatment outcomes.

- Deep blocking over wide spectral range
- Precise spectral edge placement
- Tight spectral uniformity
- Steep spectral edges

Tattoo removal and similar skin treatment applications benefit from **Dichroic Beamsplitters and Mirrors** by minimizing wavefront aberrations and laser pulse broadening which enables deeper tissue penetration.

- Low reflected wavefront error (RWE) dichroic or mirror
  - Minimal aberration introduced to illumination beams upon reflection by dichroic beamsplitters
- Low transmitted wavefront error (TWE) dichroic
  - Minimal aberration introduced to illumination beams
- Pulse dispersion control with dichroic or mirror
  - Minimizes pulse broadening leading to higher peak power, deeper tissue penetration and effective treatment
  - Reduces loss of energy in the illumination fold path reducing cost of ownership

Notch filters provide deep blocking at illumination wavelengths and ensure eye safety in clinical treatments

- Notch filters with Low S/D specification and high surface quality ensure high blocking and prevent light leakage ensuring eye safety

Summary

Aesthetic laser encompasses a variety of medical procedures utilizing light-based technology for cosmetic and dermatological purposes such as skin resurfacing, hair removal, tattoo removal, and body contouring. Laser aesthetic instruments produce specific wavelengths of light that interact with skin tissues, enabling various treatments and procedures with minimal invasiveness. VIAVI offers instrument manufacturers several Light Shaping Optics products including Engineered Diffusers and Micro-Lens Arrays which enable faster treatment with uniform beam illumination, improving light throughput leading to reduced cost of instruments and faster aesthetic procedures. VIAVI Thin Film Coating products such as Bandpass/Edge Filters provide precise illumination leading to consistent treatments outcomes, Dichroic Beamsplitters and mirrors that enable deeper tissue penetration, and Notch Filters that ensure eye safety in clinical treatments. VIAVI Optical Technologies are ideal for demanding applications that require high contrast performance, wavelength agility, and 24/7 reliability while supporting manufacturers' needs deliver solutions at a low cost.

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