Scanner Optimized Efficacy (SOE) Hair Removal with the VSP Nd:YAG Lasers

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Abstract:

In laser hair removal, it is preferred for many clinical and technical reasons to use small to medium size laser spotsizes. However, manually aiming a small laser beam hundreds of times to cover a larger skin area can lead to uneven coverage and can result in missed areas and excess heating due to pulse stacking. For this reason, large beam diameters are sometimes used for hair removal. This can lead to ineffective treatments, increased occurrence of side effects and more pain to the patient. The latest Fotona SOE technology allows practitioners to apply small to medium beams without sacrificing the safety and efficacy of the treatment. This is achieved by utilizing computer controlled laser scanner mirrors to automatically place the laser beam over a larger skin area in a perfect non-sequential pattern.

Key words: laser hair removal; VSP technology, SOE technology, Nd:YAG lasers, scanner
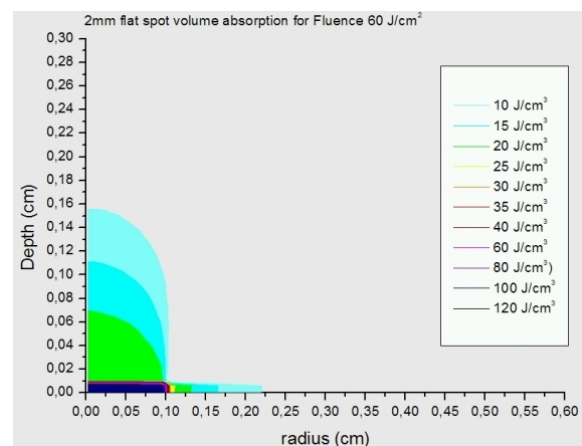
INTRODUCTION

Laser hair removal has in recent years received great interest because of its non-invasiveness, long-term results, minimal treatment discomfort, and procedure speed.[1] Commercial laser and flashlamp light (IPL) systems differ in wavelength, pulsewidth, fluence, laser beam delivery system and skin cooling methods; all of which have an effect on the treatment outcome.[2] Scientific evaluations[2] and clinical experience have shown that hair removal with VSP (Variable Square Pulse) [3] Nd:YAG lasers is one of the safest and most effective methods for light-based hair removal. This particularly applies to laser systems that use SOE (Scanner Optimized Efficacy) [4] technology to perfectly cover large skin areas with optimally sized individual beam spots.

This paper describes the technology and science behind SOE-based hair removal with VSP Nd:YAG lasers.

SPOTSIZE CONSIDERATIONS

The inexperienced laser system user may not always recognize the importance of spotsize of the emitted beam as a treatment parameter. Theoretically, if the spotsize is increased and the laser energy is simultaneously increased to maintain the same energy fluence, the clinical effect should be similar. However, due to random laser light scattering, spotsize does make a difference to the treatment outcome. As a beam propagates into the skin, light scattering spreads the beam radially outward, which decreases the beam's intensity as it penetrates into the skin. This effect is more pronounced in smaller spotsizes where the penetration depth is much lower than it would be, if only absorption characteristics were considered.

Fig. 1 shows the deposition of laser energy within the skin for three different spotsizes (2, 6 and 20 mm) for the same laser fluence of 60 J/cm². based on our computer simulations. A Monte Carlo numerical method was used to obtain these results.[5]

Fig. 3. An example of a 20 mm spot size handpiece (Fotona R34).
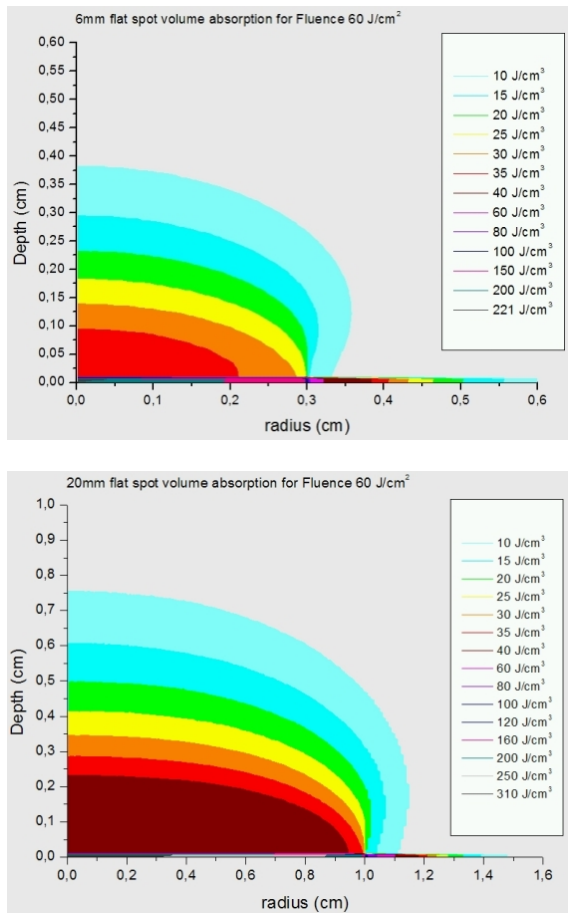
Fig. 1. Computer simulated deposition of laser energy within the skin for three different spotsizes (2, 6 and 20 mm) for the same laser fluence of 60 J/cm²

This means that in principle small spotsizes (e.g. 2-3 mm) are good for treatments where heat has to be deposited superficially in the skin, like in skin rejuvenation and vascular lesions treatments. Following the same reasoning, larger spotsizes are better for laser hair removal treatments because the aim of these treatments is to achieve thermal effects deep in the skin, where the hair follicles are located. However, the more tissue light has to thermally affect, the more energy is needed from the laser system. This means that in practice it is important to optimize the spotsize and therefore the depth of penetration to the actual depths of the hair follicles.

The depth of hair follicles inside the skin depends on the location on the body and varies from 2 - 7 mm, although most hair follicles do not lie deeper than 5mm. Laser light must therefore penetrate to a depth of at least 5 mm in the skin. With the Nd:YAG laser wavelength this is achieved with beam spotsizes between 6 and 9 mm. [Fig. 2]

BEAM PROFILE CONSIDERATION

Fluence

The fluence is usually one of the main settings for hair removal. It is defined as energy density:

$$f = E/S$$

where f is fluence, E is the energy of the laser pulse and S is the spotsize of the laser beam at the skin surface. Usually it is measured in J/cm².

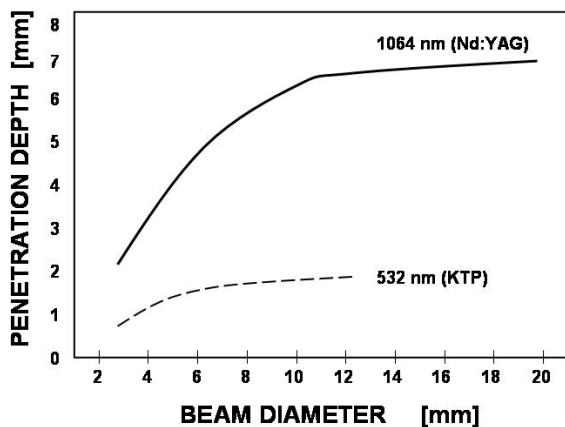Typical Nd:YAG fluence values for hair removal range between 20 to 70 J/cm² [2].

Fig. 2. Penetration depth depends on beam diameter and laser wavelength.

The depth of laser energy penetration increases with increasing spotsize. [Fig. 2] For example, the same energy deposition of 10J/cm³ is achieved at 1.6 mm, 3.7 mm and 7.5 mm (depth of efficacy) for respective spot sizes of 2, 6 and 20 mm [Fig. 3].

Beam profile

Standard laser handpieces emit beams with a

Gaussian profile with an energy distribution that resembles a conical shaped curve [Fig. 4a]. The principal effect of this is to create higher focal fluences at the centre of the spot while the fluence decreases towards the edge of the spot. Gaussian handpieces are less appropriate for laser hair removal treatments where a uniform fluence is desired over the whole spot. However, they might be very useful for treating vascular lesions.
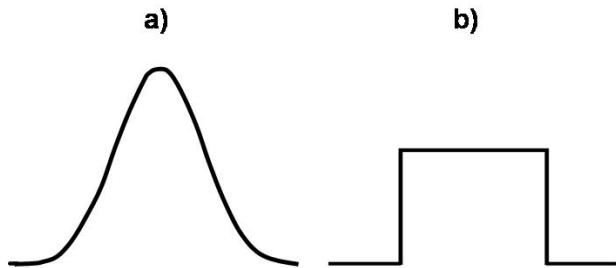

Fig. 4. a.) A Gaussian beam profile
b). A top-hat beam profile

Special *"top-hat"* profiled handpieces (such as Fotona R33, R34, and S11) have been developed for hair removal [Fig. 4b]. Because of their much more homogeneous beam profile, top-hat handpieces are much safer and effective compared to standard Gaussian profile handpieces. For example, Fig. 5 shows that for a selected fluence on the laser keyboard (which is in reality only the average fluence), a 4 mm spot with a "Gaussian" handpiece, will emit laser radiation in the center of the spot with a focal fluence twice the value of the "top-hat" handpiece, and practically zero fluence at the edges of the spot. If a 60 J/cm^2 fluence value is selected on the keyboard the "Gaussian" handpiece will emit 120 J/cm^2 at the center of the spot.
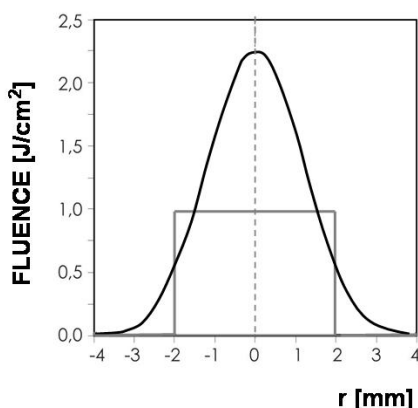

Fig. 5. Comparison of peak fluences of Gaussian and top-hat beam profiles for the same average fluence and 4 mm spotsize.

It is important to note that where a user is used to treating unwanted hair with a top-hat handpiece at certain selected fluences, a much lower fluence setting is required when working with a Gaussian handpiece. This is because for the same (average) selected fluence, the fluence at the center of the spot is much higher with a Gaussian handpiece, .i.e. 3.8 times higher with a 2 mm spot, 3.1 times higher with a 3 mm spot and 2 times higher with a 4 mm spot.

As a final note, due to optical propagation properties it is technologically preferred to use top-hat beam profiles with small or medium size spot diameters. For very large areas the top-hat profile handpieces would be inconveniently large and heavy for use.

TREATMENT SPEED AND PRECISION CONSIDERATIONS – SOE TECHNOLOGY

Larger spotsizes may be preferred by regular laser system users as they allow faster coverage of the treated area. However, this may not be the optimal choice. The process of absorbing and scattering concentrates energy in the superficial epidermal layer. The larger the spotsize, the larger the volume of skin from which laser light can be scattered back and absorbed in the epidermis. This means that the epidermis is heated more when larger spotsizes are used. Fig. 1 shows that for the same laser fluence the energy deposited in the superficial epidermal layer is 120, 221 and 310 J/cm^3 for spotsizes 2, 6, and 20 mm respectively. Consequently, although with larger spotsizes laser light penetrates much deeper into the skin, the level of unwanted epidermal heating increases. To avoid this effect, it is advisable to reduce fluences as spotsizes are increased, or to significantly increase the level of epidermal cooling. These two factors combined indicate that while larger spots penetrate much deeper into the skin they are not necessarily as safe and comfortable as medium spotsizes.

To strike the right balance between spotsize, fluence and penetration depth, SOE (Scanner Optomized Efficacy) technology has been introduced. SOE is based on a computer-controlled scanner with:

a) Optimally sized individual beam spots.

b) Top-hat profile individual beam spots.

c) Adjustable individual beam spotsizes from 3 to 9 mm.

d) Optimal non-sequential scanning for higher safety and patient comfort

e) Perfect coverage of the skin area with adjustable overlap between adjacent spots

f) Adjustable rectangular scan up to an unprecedented scanner area of 42 cm² (6.5 cm x 6.5 cm)

g) The fastest scan rate due to the highest power (130 W) VSP Nd:YAG laser source.

h) Completely non-contact hair removal

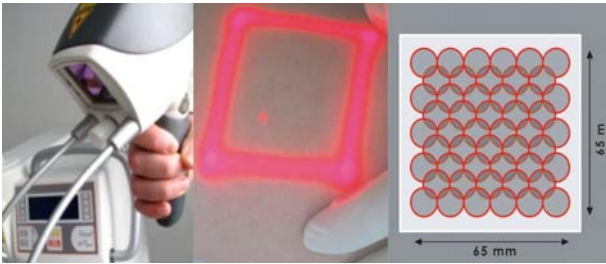i) Possibility of pre-, and post-treatment air cooling

Fig. 6: An example of SOE technology: a VSP Nd:YAG laser scanner (Fotona S-11)

A scanner allows the use of medium spotsizes to cover large skin areas without sacrificing treatment speed and efficiency. Advanced scanners, such as the S-11 from Fotona, utilize top-hat distribution technology to minimize hot spots in the scanning pattern [Fig. 7]. The S-11 scanner also allows users to select a small spotsize (3 mm) for shallower skin rejuvenation treatments, and medium spotsizes (6 mm and 9 mm) that are capable of penetrating deep enough to ensure effective hair removal treatments while maximizing patient safety and comfort. Combined with a large scan area (6.5cm x 6.5cm = 42cm²) and high coverage speeds, the S-11 scanner is one of the most efficient means of providing laser hair removal.
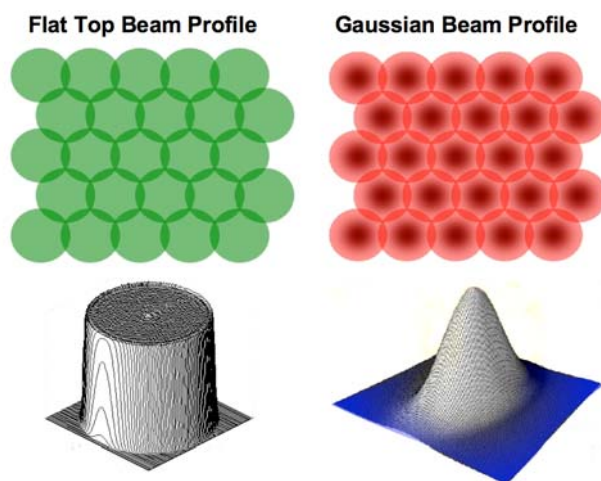

Fig. 7. Top-hat profile scanning pattern without *"hot-spots"* compared to Gaussian profile scanning pattern

with hot-spots.

Another important advantage of using a scanner is that spots can be placed far more precisely than manually covering the same area with a handpiece and individual spots. Ideally, visual tissue effects are minimal during laser hair removal treatments and it is therefore quite difficult to distinguish treated areas from non-treated ones. Inevitably the area covered with a scanner is larger than the area covered with individual spots, which simplifies the alignment of treatment passes over the treatment area. The risk of accidental overlap and thus excess thermal heating and spread is decreased. The use of a scanner decreases treatment time, increases the precision of energy placement on the tissue, therefore decreasing fatigue and ensuring treatment safety.

EPIDERMAL COOLING CONSIDERATIONS

Light-based hair removal inevitably requires laser light to pass first through the epidermis before reaching the to-be-treated hair follicle. For this reason, it is important to be able to reduce any unnecessary heating of the epidermis by all means, to ensure patient comfort and avoid any irreversible damage to the skin. Epidermal cooling can be particularly helpful when treating patient with darker skin types. Besides choosing the laser wavelength with the lowest absorption in the epidermis, and tailoring the laser pulsewidth, epidermal cooling methods should be considered.

Several skin cooling methods are available [2], all of which extract heat by conduction into an external, cold medium. The rate of epidermal cooling depends on temperature, contact quality, motion, and thermal properties of the external medium. An optimal cooling method should cool the epidermis, while not cooling the hair shaft excessively.

Cold air cooling is the latest method for active skin cooling. It delivers a continuous flow of chilled air before and after the laser exposure (pre- and post-cooling). Besides, cold air cooling is ideally suited for SOE-guided hair removal treatments as it can simultaneously cool the entire laser scan area. It provides more comfortable treatments (better analgesic effect for patients) and unlimited post-treatment cooling. Post-treatment cooling is important as it has been shown to reduce side effects and healing time. With cold air the treatment is more practical, safer and more pleasant. Faster treatments are possible since there is no need for time intervals to apply a cryogenic spray or contact cooling. The treatment area remains visible at all times during the treatment. The procedure is not dependent on surface topography facilitating access to specific more complex areas i.e.

bikini, intergluteal fold, ears, nostrils, etc. Furthermore, with this non-contact cooling method, there is no medium disturbing of the path of the laser beam and no interface inducing losses caused by dispersion, transmission and reflections. Finally, it has no disposable requirements.

PATIENT COMFORT CONSIDERATIONS

Long-term clinical experience has shown that the use of a scanner significantly reduces discomfort during the treatment. This is due to two reasons:

a) Smaller individual beam spotsizes are used to scan large skin areas. The sensation of pain also increases with the laser spotsize. The larger the spotsize, the more discomfort is felt by the patient [Fig. 10]. For this reason it is advisable not to use spotsizes that are larger than needed to reach the necessary depth where hair follicles are located. Scanning a large area with a large number of smaller laser spots with a scanner is therefore preferable to covering the same area with a small number of laser spots.
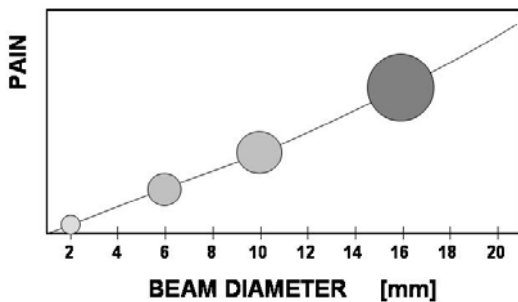

Fig. 10 : Dependence of pain sensation on the laser beam spot diameter

b) Non- sequential coverage of skin areas. Since the coverage is computer-controlled, laser spots do not have to be applied onto the skin sequentially next to one another, as would be the case in a manually performed treatment. This allows heat to dissipate before adjacent hairs are treated, resulting in greater safety and comfort. The Fotona S-11 scanner is able to scan the entire scan area during the given time period without ever depositing one spot directly next to another. The scanning sequence 'skips' spots and lines, with the 'gaps' being filled in progressively with each pass. In this way it requires four passes to cover the entire scan area completely, doing this as fast as a single 'Sequential' pass. Such scanning sequence allows the user to perform hair removal treatments that require high fluence settings at high repetition rates.

SOE HAIR REMOVAL- CONCLUSIONS

Using small to medium laser beams is beneficial for many reasons:

a) Lower pulse energies are required which leads to higher available fluences and shorter pulsewidths for treating a greater variety of hairs.

b) Top-hat beam profiles may be used which leads to higher safety and efficacy

c) Back scattering to the epidermis is reduced resulting in reduced side effects

d) Reduced pain sensation and therefore higher comfort and higher possible treatment speed.

Manually aiming a small laser beam hundreds of times to cover a larger skin area can lead to uneven coverage and can result in missed areas and excess heating due to pulse stacking. Also, the laser must be placed with millimeter precision over the entire area, an impossible task as it is difficult to determine the treated area accurately.

SOE (Scanner Optimized Efficacy) technology eliminates these problems by utilizing computer-controlled laser scanner mirrors to automatically place the laser beam in a perfect non-sequential pattern [Fig. 11]
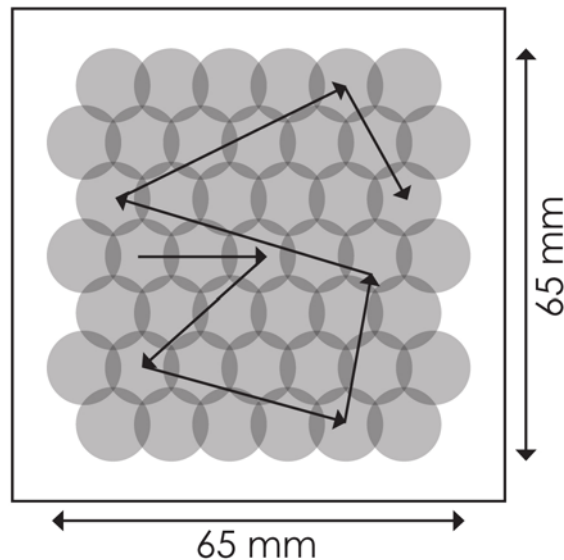

Fig. 11: Non-sequential SOE pattern with perfect coverage of the entire skin area.

SOE is rapid, precise, consistent and comfortable. It eliminates fatigue, and every treatment is identical regardless of who performs the treatment. SOE is used to treat large rectangular areas of various sizes by quickly filling the entire area with uniform energy at high fluence values. The result is a comfortable, uniform laser hair removal treatment without hot spots, less wasted energy, more comfort and safety.

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