# Laser Hair Reduction and Non-Ablative Laser Skin Rejuvenation*

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**ABSTRACT**

In 1983, Anderson and Parrish shared their theory of selective photothermolysis, shedding light on how, by controlling the wavelength, pulse duration and fluence of lasers, we can selectively destroy target tissues while minimising unwanted collateral damage. To illustrate this theory and the evolving use of lasers in the healthcare industry, we cite two of the more recently developed applications, laser hair reduction and non-ablative laser skin rejuvenation.

*Keywords*: depilation, laser, rejuvenation

## HISTORY

The term LASER stands for light amplification by the stimulated emission of radiation. It was Albert Einstein who first explained the theory in his 1917 work, *The Theory of Stimulated Emission of Radiation*. Putting this theory into practice and developing the first laser took another 4 decades. This feat is generally credited to Theodore Maiman who fabricated the first ruby laser by wrapping a simple man-made ruby crystal polished on both ends in a flash tube. Since then, lasers have had profound effects in a myriad of diverse ways. Conceived in the communications industry and nurtured in the entertainment industry, the laser is inevitably pervading the healthcare industry. Much of this is owed to Leon Goldman, MD, commonly referred to as the father of laser medicine; this pioneering dermatologist performed much of the early work in developing the medical and surgical laser applications.[1]

## SELECTIVE PHOTOTHERMOLYSIS

Anderson *et al* stated in their theory of selective photothermolysis (SPTL) that selected thermal damage of a pigmented structure results when a sufficient fluence at a wavelength preferentially absorbed by the target is delivered within a time equal to or less than the thermal relaxation time of the target.[2] Thus, selective destruction of pigmented targets can be achieved by controlling 3 variables of the laser: wavelength, pulse duration and energy loading of the tissue.

When light or laser energy strikes tissue, it can be scattered, reflected, transmitted or absorbed. Only the light which is absorbed by that tissue has any specific effect on it. The effects can be (i) thermal, in the form of protein denaturation or carbon formation, (ii) chemical, with the formation of reactive chemical molecules, and (iii) mechanical, with resultant photoacoustic changes. Transmission of the laser beam allows the targeting and destruction of deeper structures without adversely affecting more superficial tissues. Scattered laser energy is important in achieving effects on target structures which are too deep or large for directly absorbed energy to affect. The structures within skin which are responsible for light absorption are termed *chromophores*. The common skin chromophores are melanin, haemoglobin, water and exogenous substances such as tattoo ink. These various chromophores preferentially absorb light over different wavelength spectra (Fig. 1). Thus, the selection of which laser to employ should be based primarily on the absorption coefficient of its wavelength for the target chromophore.

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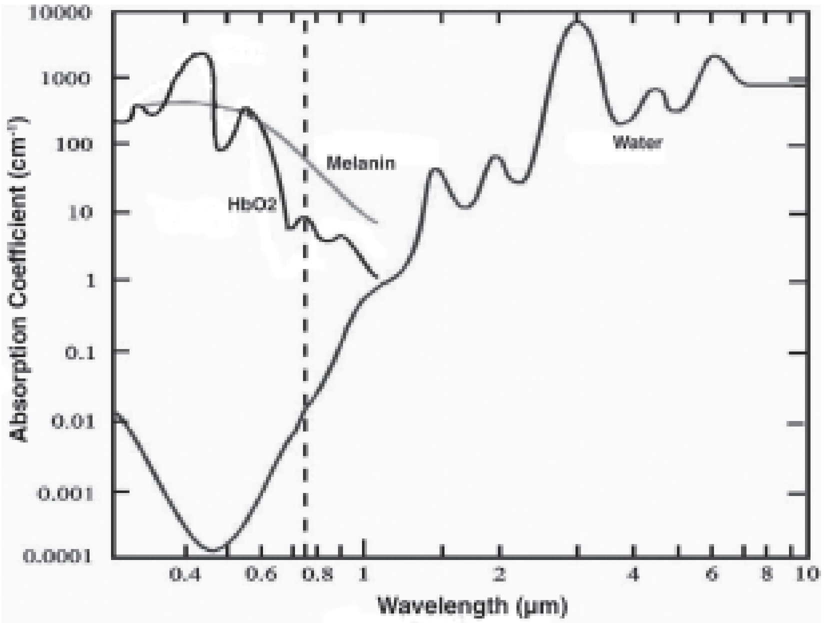


Fig. 1. Absorption spectra of the various skin chromophores.

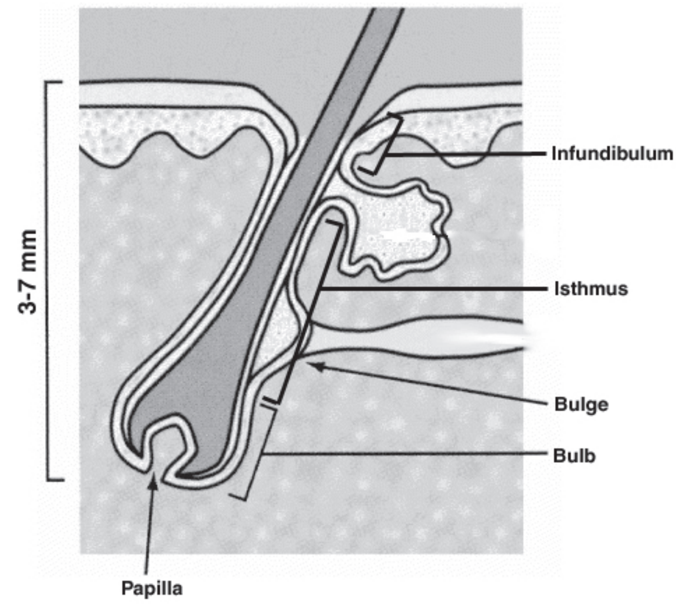


Fig. 2. Anatomy of a typical hair follicle.

The *thermal relaxation time* of tissue is the time taken for it to lose 50% of its heat through diffusion. It is represented by the formula:

$TRT = d^2/16K_d$

d = diameter of the chromophore

$K_d$ = thermal diffusion constant

The pulse duration of the laser has to be shorter than the thermal relaxation time of the target chromophore to be effective. A shorter pulse duration ensures that the majority of the heat energy and subsequent damage is kept within the target tissue without adversely affecting surrounding structures.

The third factor important in SPTL is energy loading or fluence ($J/cm^2$). The fluence must exceed the ablation threshold, or more appropriately, *therapeutic threshold* for that tissue. Below this threshold, all that results from the absorption of light energy is an undesirable heating of the target. At fluences exceeding

Table 1. Richards-Meharg body and head hair growth table.

| | Percentage of resting hairs in **Telogen** | Percentage of growing hairs in **Anagen** | Duration of growth time in **Telogen** | Duration of growth time in **Anagen** | No. of follicles/cm$^2$ | Daily rate of growth |
|---|---|---|---|---|---|---|
| Head | | | | | | |
| Scalp | 13 | 85 | 3-4 months | 2-6 years | 350 | 3–5mm |
| Eyebrows | 90 | 10 | 3 months | 4-8 weeks | | 2–2.5mm |
| Ear | 85 | 15 | 3 months | 4-8 weeks | | |
| Cheeks | 30-50 | 50-70 | | | 880 | 2–4mm |
| Beard-chin | 30 | 70 | 10 weeks | 1 year | 500 | 2–4mm |
| Moustache/Upper lip | 35 | 65 | 6 weeks | 16 weeks | 500 | 1–2.5mm |
| Body | | | | | | |
| Axillae | 70 | 30 | 3 months | 4 months | 65 | 3.5–4.5mm |
| Trunk | NA | NA | | | 70 | 2–4.5mm |
| Pubic area | 70 | 30 | 3 months | 4 months | 70 | 3.5–5mm |
| Arms | 80 | 20 | 18 weeks | 13 weeks | 80 | 2–4.5mm |
| Legs & thighs | 80 | 20 | 24 weeks | 16 weeks | 60 | 2.5–4mm |
| Breasts | 70 | 30 | | | 65 | 3–4.5mm |

the therapeutic threshold, ablation of the target is achieved; this is provided the energy loading is accomplished in less than the thermal relaxation time to prevent dissipation of heat energy to adjacent structures.

## LASER HAIR REDUCTION

*Permanent hair reduction* is defined as a significant reduction in the number of terminal hairs after a given treatment, a reduction that is stable for a period of time longer than the complete natural hair growth cycle. The length of the cycle varies from 4 to 12 months depending on body location. Prior to the last decade, the only long-lasting method of hair reduction was electrolysis. Electrolytic depilation, however, is slow, painful and requires multiple treatments. It is also accompanied by a small but definite risk of scarring and infection. Goldman *et al* first noticed ruby laser injury to hair follicles in 1963.[1] It was only over the past 8 years, however, that laser depilation emerged as a viable modality. Compared to electrolysis, laser hair reduction requires fewer treatments and is associated with fewer complications, though temporary skin pigmentary changes can occur. The lasers commonly used for hair reduction are:

1. Long-pulse ruby lasers (694nm)
2. Long-pulse alexandrite lasers (755nm)
3. Pulsed diode lasers (800nm)
4. Q-switched or long-pulse Nd:YAG lasers (1064nm)

### *Hair Biology*

The general anatomy of an individual hair is shown in Figure 2. Each hair has 3 distinct regions: the bulb, the isthmus and the infundibulum. Hair growth occurs from the pluripotential cells located in the bulb and bulge areas of the hair follicle which are 3 to 7mm and 1 to 1.5mm deep, respectively. Melanocytes are located in these areas. All hairs undergo a cycle of active growth (anagen), transition (catagen) and resting (telogen) phases. The hair length at differing body sites is determined by the duration of the anagen phase.[3] During anagen, the hair matrix cells are rapidly dividing and the melanin target is largest. For these reasons, the laser is most effective during the active growth phase. As not all hairs in the same region are in anagen concurrently, depilatory sessions need to be repeated to capture hairs emerging in the growth phase. For a reasonable reduction in hair count, to an extent that future treatments achieve no significant reduction in hair volume, 2 to 6 sessions may be required. Table 1 summarises the characteristics of hairs with respect to different body sites.[4]

### *Hair Laser Physics*

The target chromophore is the melanin in the hair follicle; the competing skin chromophores include melanin and haemoglobin. The specific targeting of melanin within the hair follicle and not the skin relies on an extension of the principle of SPTL, *thermokinetic selectivity.* The thermal relaxation times of the epidermis and the hair follicle are 3 to 10ms and 40 to 100ms respectively. The disparity between the 2 is due to the difference in chromophore size, with that of the hair follicle being significantly larger. The pulse duration of the depilatory laser must therefore be longer than 10ms and shorter than 40ms to achieve destruction of the hair follicle while minimising skin damage due to the competing epidermal melanin.

For laser depilation to be successful, the energy must be delivered to a minimum of 4mm depth. Penetration of the light energy to this depth is achieved in several ways:

1. use of a *longer wavelength* achieves deeper penetration than do shorter ones
2. use of a *larger spot size* increases depth penetration as a lower proportion of the beam is scattered.
3. absorption or scatter by haemoglobin within the skin capillary network can be minimised by *compressing* the skin during the time of laser treatment to empty these vessels
4. reflection can be minimised by *direct contact* of the laser handpiece against the skin, thus eliminating the air-skin interface

Laser hair reduction is not a painless procedure. Most patients experience some discomfort both during and immediately following treatment. Epidermal damage may occur if high fluences are used; bacterial infection may rarely supervene. Transient hypopigmentation or hyperpigmentation are more common in darker-skinned individuals, whilst permanent changes are unlikely. Permanent scarring is rare and is usually the result of over-aggressive treatment or infection.

## NON-ABLATIVE LASER FACIAL REJUVENATION

Laser facial rejuvenation may be either ablative or non-ablative. Ablative laser rejuvenation is characterised by top-to-bottom injuries, requiring epidermal injury to achieve subsequent remodelling and restoration. While ablative techniques are effective, their invasive nature leads to several drawbacks. They generate significant discomfort, require extensive convalescent post-operative wound care and they can be complicated by pigmentary alterations and scarring.[5] This article will focus only on non-ablative laser rejuvenation; ablative, non-laser light or radiofrequency devices will not be discussed.

Non-ablative techniques preserve epidermal viability. Non-ablative lasers effect rejuvenation either by targeting discrete chromophores in the dermis or at the epidermal-dermal junction, or by using midinfrared wavelengths at which absorption by water is weak enough that relatively deep beam penetration occurs. At wavelengths 1.3 to 1.55μm, there is only 50% beam attenuation at depths of 300 to 1500μm. Based on these mechanisms, the lasers used in non-ablative rejuvenation may be categorised as follows:

1. Lasers that target discrete chromophores
   i) Pulsed dye lasers (585 or 595nm)
2. Lasers that target discrete chromophores and tissue water
   i) Q-switched Nd:YAG lasers (1064nm)
   ii) Diode lasers (980nm)
3. Lasers that target exclusively tissue water
   i) Erbium glass laser (1.54μm)
   ii) Nd:YAG laser (1320nm)
   iii) Diode lasers (1.45μm)
   iv) Er:YAG lasers (2940nm)

With lasers that target discrete chromophores, it is postulated that the mechanism of action occurs at both epidermal and dermal layers. At the epidermal layer, absorption by melanin reduces uneven pigmentation leading to improved skin *tone*. At the dermal layer, the laser pulse is absorbed by haemoglobin and induces an inflammatory response in the skin dermal vessels. This results in the release of inflammatory mediators from the vascular endothelial cells causing increased fibroblast activity with subsequent new collagen formation and increased dermal thickness.[6] This manifests itself as improved skin *texture*.

Non-ablative rejuvenating lasers that target tissue water have longer wavelengths and achieve deeper penetration. As water is ubiquitous in the skin, preservation of the epidermis requires protection by surface cooling applied before, during and sometimes, after the laser pulse. These lasers heat the dermal collagen to which water is inextricably bound. Collagenesis is stimulated via this gentle dermal heating.[7]

Non-ablative lasers have few possible adverse effects. Bruising may occur due to damage to the superficial skin vessels; epidermal damage occurs rarely and can usually be avoided by adequate surface cooling. Because of their limited side-effect profile, ease of treatment and minimal discomfort, these lasers are ideal for individuals unable to sacrifice the time needed for recovery from ablative resurfacing techniques.

## CONCLUSION

The use of medical and surgical lasers in the healthcare industry is evolving on a logarithmic scale. Laser hair reduction and non-ablative laser facial rejuvenation are just 2 examples of the numerous applications which have emerged over the past decade.

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