Specifics of using diode lasers on different skin and hair types

Viktoriia Chernychko [1]

Received: 2025-09-02
Accepted: 2025-10-02
DOI: https://doi.org/10.5281/zenodo.17980578

Abstract. The article is devoted to the analysis of modern laser hair removal technologies with an emphasis on diode lasers, their wavelength and effect on different skin and hair types. The purpose of the article is to describe the features of the technology of using diode lasers for hair removal on different skin types. During the scientific research, general scientific methods of cognition were used: analysis, synthesis, induction, deduction, systematization, comparison, generalization and modeling. The results of the study show that the key mechanism of action of laser hair removal remains the principle of selective photothermolysis, in which light energy of a certain wavelength is selectively absorbed by melanin in the hair follicle, causing its thermal damage with minimal impact on surrounding tissues. Diode lasers with a wavelength of 800-810 nm have been shown to be the most versatile in clinical practice, as they combine high efficacy with a good safety profile for patients with skin phototypes III-V. Special attention is paid to three-wave diode systems (810+940+1060 nm), which provide more uniform heating of the follicle, minimizing the risks of overheating the epidermis, especially in patients with dark skin. It has been shown that wavelengths of 940 and 1060 nm are characterized by reduced melanin absorption in the epidermis and better penetration into the deeper layers of the dermis, which makes them effective and safe for phototypes IV-VI. In clinical conditions, these systems have demonstrated high efficacy, reducing hair density by up to 66% even on thin or poorly pigmented hair. It is concluded that diode lasers are the modern standard in the field of laser hair removal, due to the flexibility of settings, clinical effectiveness and high safety profile for different skin types. The use of combined wavelengths enhances the therapeutic effect and allows for an individual approach to the patient. The practical significance of the study is to provide scientifically based recommendations for the safe and effective use of diode lasers for hair removal, taking into account the skin phototype and hair structure.

Keywords: laser hair removal, diode laser, wavelength, skin phototype.

[1] Specialist in Aesthetic Machine Cosmetology,
Owner of Chernika Beauty SpaceRenton and Mill Creek, WA
Sumy State Pedagogical University named after A.S. Makarenka, Ukraine
E-mail: chernika.beauty.space@gmail.com
ORCID: https://orcid.org/0009-0004-7999-0592

Introduction

The US laser hair removal market operates at the intersection of intense economic growth, technological differentiation, and a selectively stringent but fragmented regulatory environment. According to market analysis, the US laser hair removal market was valued at $422 million in 2025 and is expected to grow to $961.9 million by 2030, representing a projected compound annual growth rate (CAGR) of 17.9% from 2023 to 2030 [6]. This trend reflects the gradual transformation of laser hair removal from a relatively niche aesthetic service into a large commercial segment integrated into the broader cosmetic and dermatological treatment market. Globally, the US is the leading market for laser hair removal. In 2022, the United States accounted for 27.7% of the global laser hair removal market in terms of value [6]. According to forecasts, the USA will maintain its leading position in terms of revenue in 2030 both globally and within North America.

The structure of the market by type of laser systems reflects both technological progress and the specifics of demand from consumers and service providers. In 2025, the largest amount of revenue was accounted for by diode lasers, which are recognized as the largest market segment in terms of revenue [6]. The functioning of the market in the USA is largely determined by the activities of the world's leading manufacturers of laser hair removal equipment. Key players include Cynosure, Alma Lasers Ltd, Bausch Health Companies Inc, Cutera Inc, Candela Medical, Lumenis, Venus Group, Sinclair Pharma plc and UltraShape Ltd. [6]. For the American market, this means a high degree of technological saturation, constant updating of equipment lines, as well as the presence of an extensive network of service support, training programs and clinical protocols, which indirectly affect the quality of services provided to end users.

However, an important feature of the functioning of the laser hair removal market in the USA is that its institutional and legal framework is not unified at the national level. In the USA, the main regulatory mechanisms for the training and admission of operators to work with laser systems are formed at the level of individual states. In the USA, the first state to introduce mandatory training hours for working with light technologies, including laser hair removal, was Arizona. To obtain the right to work with laser systems in the field of hair removal, candidates are required to undergo 40 hours of theoretical training, and to obtain the status of Senior Laser Technician, a prerequisite is the observation of at least 100 laser hair removal procedures on specific areas of the body performed by a registered specialist [9]. This approach allows you to collect and process a significant amount of clinical data, which become the basis for scientific research by numerous authors.

Literature Review

Since laser hair removal is a fairly common cosmetic procedure, a large number of publications have been accumulated to date, devoted to its technological features, clinical aspects of implementation and evolution of approaches to hair removal using different types of laser systems. Among them, diode lasers are the object of special attention, given their effectiveness, safety and adaptability to different types of skin and hair. In the literature, one can find comparative studies with other technologies, as well as reviews of the latest developments, such as multi-wavelength diode systems. A significant contribution to the study of this issue was made by such authors as Al-Hamamy H. [1], Countney E., Goldberg D.J. [2], Gan S.D., Graber E.M. [4], Goldberg D.J. [5], Pall A., Viera Mármol G. [7, 8], Thomas M.M., Houreld N.N. [9], Town G., Brown E.R. [10], Vaidya T., Hohman M.H., Dinesh Kumar D. [11], who considered both the clinical effects of using a diode laser with a wavelength of 808/810 nm and the latest technological solutions in the field of laser hair removal.

It is worth noting the use of a professional technology review from the DDC Technologies website [3], which analyzes in detail different types of laser systems, as well as statistical and

market data from the Grand View Research marketing report [6], which illustrates the trends in the development of the laser hair removal market in the USA.

The purpose of the article is to describe the features of the technology of using diode lasers for hair removal on different skin types.

Research Results

Modern laser hair removal technologies are based on the principle of selective photothermolysis, when light energy of a certain wavelength is selectively absorbed by melanin in the hair follicle, converted into heat and causes its thermal damage with minimal impact on surrounding tissues [4]. The effectiveness and safety of the procedures are determined by a combination of three key parameters:

1) wavelength;

2) pulse duration;

3) energy density (fluence).

These three indicators must be adapted to the skin phototype, hair color and thickness, as well as the depth of the follicles [3] (table 1).

Table 1 - Description of different skin and hair types

Skin phototype (Fitzpatrick)	Description of skin and hair
I	Very fair, milky-white skin, often with freckles; always burns, does not tan.
II	Fair skin (creamy, pale beige), burns easily, sometimes develops a light tan. Hair is mainly light blond or light brown, from fine to medium thickness, with moderate density.
III	Light olive or beige-tan skin, may burn slightly but gradually tans well. Hair is usually dark blond or brown, of medium thickness; body hair is more pronounced.
IV	Tan, olive or light brown skin, rarely burns, tans easily and deeply. Hair is predominantly dark brown or black.
V	Dark brown skin with a high melanin content, almost never burns, tans quickly and intensely. Hair is usually dark brown or black, coarse, often curly.
VI	Very dark, almost black, heavily pigmented skin, practically never burns. Hair is black, coarse, dense and usually curly.

Source: [3]

In clinical practice, particularly in the United States, this has led to the formation of four main technological platforms:

1) long-pulse alexandrite lasers;

2) diode lasers;

3) NDYAG (Neodymium-doped Yttrium Aluminum Garnet) lasers;

4) Intense Pulsed Light (IPL) systems.

Each of these technologies has a specific range of indications, limitations, and optimal application parameters. Let us consider each of the technologies briefly to understand their key features and differences.

The alexandrite laser with a wavelength of 755 nm is one of the oldest, but still extremely relevant technologies for laser hair removal, which is characterized by a high energy

absorption coefficient by melanin [4]. Due to this, alexandrite provides a very pronounced effect on dark hair in patients with fair skin, primarily with Fitzpatrick phototypes I-III.

Diode lasers with a wavelength of 800-810 nm occupy a central place in modern clinical practice and are often described as the "workhorse" of the laser hair removal market [3]. Compared to alexandrite, the diode laser is characterized by slightly lower melanin absorption, but deeper penetration into the dermis, which allows it to effectively affect thicker and deeper follicles, particularly on the back and limbs [4].

The NdYAG laser with a wavelength of 1064 nm is a key technology for patients with dark skin phototypes, in particular IV-VI, due to the lowest level of melanin absorption among "classic" hair removal lasers and the deepest tissue penetration [4]. Less energy absorption by epidermal melanin reduces the risk of superficial burns and pigmentation disorders, making the NdYAG laser the "gold standard" for hair removal in dark-skinned patients and tanned skin, provided that the fluence and pulse duration are properly selected [4]. Intense pulsed light (IPL) systems, which are often mistaken for lasers, are actually broadband light sources in the range of approximately 590-1200 nm using filters to select a part of the spectrum [3-4]. Unlike monochromatic lasers, IPL provides a less selective effect on the target, therefore, in the context of hair removal, its effectiveness and safety largely depend on the experience of the operator, the accuracy of the choice of parameters and strict patient selection. IPL is considered optimal for use in patients with fair skin (mainly phototypes I-II, sometimes I-III with caution) and dark hair, since darker phototypes significantly increase the risk of burns and post-inflammatory pigmentary changes due to more pronounced absorption of light by epidermal melanin.

All these technologies implement the same physical principle of selective photothermolysis, but differ in the balance between selectivity to melanin, penetration depth, safety for different skin types and clinical versatility, which determines the choice of a specific platform in a particular clinical context. A comparison of the technical characteristics of lasers is given in Table 2.

Table 2 - Comparative characteristics of the operation of different lasers

Technology	Wavelength, nm, and optimal phototypes	Hair characteristics	Key advantages
Long-pulsed alexandrite	755; I–III	Dark, medium thickness, may be fine	Advantages: very high selectivity for melanin, fast procedures, large spot sizes; disadvantages: high risk of adverse effects in phototypes IV–VI, unsuitable for dark and tanned skin
Long-pulsed diode laser	800–810; III–V	Medium and coarse hair, deeper location	Advantages: compromise between efficacy and safety, deeper penetration, high versatility; disadvantages: lower efficacy on very fine or light hair
Long-pulsed Nd:YAG	1 064; IV–VI	Dark, coarse hair, deep follicles	Advantages: safe for dark and tanned skin, maximal penetration depth; disadvantages: lower efficacy on fine or light hair, more painful without adequate cooling
IPL	590–1 200; I–II	Predominantly dark hair	Advantages: low cost, multifunctionality (epilation, pigmentation, vascular lesions, acne); disadvantages: increased risk of burns in darker phototypes

Note: systematized by the author based on sources [3-4]

Diode lasers occupy a central place in the modern system of laser hair removal and are considered one of the leading technological standards for hair removal. Most clinical systems operate at a wavelength of about 810 nm, which belongs to the long-wave infrared range and provides sufficient energy absorption by melanin in the hair follicle while reducing the fraction of absorption in the epidermis compared to shorter wavelengths [11]. It is this combination of parameters that allows you to achieve clinically significant hair reduction, provided that the fluence, pulse duration and operating mode are optimally selected, while reducing the risk of thermal damage to the superficial layers of the skin, especially in patients with higher phototypes.

The effectiveness of long-pulsed 810-nm diode lasers is confirmed by both clinical and histological data. According to StatPearls, in studies using a long-pulsed 810-nm diode laser, hair reduction ranged from approximately 22% to 59%, with histological analysis demonstrating statistically significant reductions in follicular density and hair thickness after treatment [11].

A key advantage of diode lasers, which is directly related to their wavelength, is their better safety profile in patients with darker skin phototypes compared to shorter-wavelength lasers. StatPearls states that long-wavelength systems, particularly diode and 1064-nm NdYAG, are the treatment of choice for dark-skinned patients because they are associated with fewer adverse events, such as pain and post-inflammatory hyperpigmentation, compared to short-wavelength systems [11].

Of particular note is the evolving view on the optimal treatment parameters for diode systems. While the paradigm of high fluences as a necessary condition for achieving stable follicle destruction previously dominated, current data suggest that a low fluence approach can be effectively used. Vaidya et al. note that in a number of studies, the use of low energies, in the range of approximately 5-15 J/cm^2, in combination with an appropriate pulse regimen, provided hair reduction comparable to high fluence systems, but with less discomfort and a lower incidence of side effects, even in patients with phototype V and tanned skin [11]. Most often, only mild and transient erythema and reversible pigmentary changes were recorded, without long-term undesirable effects. At the level of the mechanism of action, it is assumed that low-fluence diode systems may not so much completely destroy the follicle stem cells, as occurs with classical high-fluence selective photothermolysis, but rather induce miniaturization of thick terminal hairs and photomodulation of germ cells, which ultimately changes the hair growth cycle. This is an important conceptual shift, which shows that clinical effectiveness can be achieved even at the expense of “softer” exposure schemes. The practical dimension of the use of diode lasers in real clinical conditions is well illustrated in the mini-review by Thomas and Houreld [10]. The authors emphasize that in recent years, diode systems have become the de facto “gold standard” of laser hair removal on a global scale, especially in the context of overcoming the limitations associated with the treatment of patients with darker skin.

In a study [10] of 368 patients with phototypes III-V, the use of an 810-nm diode laser in a five-session protocol on the face and other anatomical areas demonstrated high levels of patient satisfaction and treatment acceptance, high hair reduction efficacy, and low incidence of adverse events. To achieve the desired energy dose at low fluence, the authors emphasize the importance of an “in-motion” technique, where the handpiece is moved at a constant speed to distribute the energy evenly over the treated surface [10].

Another study on 71 patients with phototypes IV-VI, where the same 810-nm diode laser and the “in-motion” technique were used for 5-6 sessions with intervals of 1-3 months, showed a very high level of satisfaction: over 80% of the participants rated the result as “excellent”, while the vast majority noted minimal or no discomfort, and the authors did not record any serious complications or persistent side effects [5]. Thus, the data presented

confirm that, if the recommended parameters are observed, diode systems can be safely and effectively used even in patients with the darkest skin phototypes.

Taken together, these results allow us to outline several key features of the operation of diode lasers, which directly follow from the sources considered (Table 3).

Table 3 - Features of the use of different wavelengths of diode lasers on different skin and hair types

Wavelength	Key efficacy and safety features	Specialist comments on hair and therapy
810 nm	This wavelength is the most commonly used in diode lasers for hair removal, as it offers a good balance between melanin absorption and penetration into the dermis. Irradiation at 810 nm provides a marked reduction in hair growth without serious adverse effects and can maintain results for up to 6 months after treatment.	Penetrates more deeply into the dermis, targeting dark hair follicles and achieving high hair-reduction rates even in intermediate phototypes; compared with IPL, shows higher levels of hair-density reduction [2].
810 + 940 + 1060 nm (triple wavelength)	The combination reduces energy absorption by the skin due to the longer wavelengths, which lowers the risk of burns, while maintaining high hair-reduction rates through improved deep penetration and more even heating of the follicles.	On fine and lightly pigmented hair, it delivers consistently high reduction rates (around 66%); the combinational mode allows the use of higher fluence with minimal risks, thanks to lower absorption by skin melanin [7].
940 nm	The 940 nm wavelength is longer than 810 nm and is less absorbed by epidermal melanin, which enables safe use in darker phototypes at high fluence and for deeply located follicles.	In combined mode, it promotes deeper follicular heating without excessive skin heating, increasing efficacy in darker phototypes without raising the risk of adverse effects [8].
1060 nm	The 1060 nm wavelength has even lower melanin absorption, which makes it possible to increase fluence without increasing thermal stress on the skin, especially in darker phototypes.	When combined with longer wavelengths, it provides more uniform penetration and irradiation of deep follicles, improving overall hair-removal efficacy and safety [8].

Note: systematized by the author based on sources [7-8]

Thus, the wavelength of the diode laser directly affects the depth of penetration and the degree of absorption by melanin. 810 nm is the standard and demonstrates high efficiency for a wide range of skin phototypes. Longer wavelengths (940 nm and 1060 nm), especially in combination in three-wave diode lasers, reduce the risk of burns and side effects in darker phototypes due to less absorption by epidermal melanin and deeper heating of the follicle itself. This enhances the therapeutic effect without harming the skin tissues, which is especially important for patients with dark skin (IV-VI).

Conclusions

The modern laser hair removal market demonstrates a steady dominance of technologies that combine high melanin selectivity with safety solutions for different ranges of skin

phototypes, forming a demand structure in which diode and combined lasers with a combination of different wavelength ranges occupy the main share. Such lasers are gradually replacing the old generation single-wave solutions, which today are more likely to be considered as a multifunctional but less selective tool with limited flexibility of parameters.

Laser technologies are distinguished by a balance between penetration depth, melanin selectivity and safety profile for skin of medium and darker phototypes, which leads to optimization of the choice of wavelengths depending on the clinical task. Diode systems provide sufficient effectiveness on light and dark hair and can be safely used in patients with a stronger tan, provided that low-impact protocols and adequate cooling are used.

However, different wavelength ranges affect skin and hair differently due to differences in melanin absorption characteristics and penetration depth. Shorter wavelengths up to 755 nm demonstrate the highest selectivity for melanin and are used mainly on the first three skin phototypes. Waves in the range of 800–810 nm are used for phototypes 3–5, sometimes even 5–6, provided that the parameters are correctly set and the thermal load is controlled. Longer wavelengths up to 1064 nm allow laser hair removal for patients with dark skin, although the effectiveness of this technology is somewhat reduced due to lower selectivity for melanin.

References

1. AL-Hamamy H., Saleh A., & Rashed Z. Evaluation of effectiveness of diode laser system (808 nm) versus IPL. *International Journal of Medical Physics, Clinical Engineering and Radiation Oncology*, 2015, 4, 41-48. URL: https://www.researchgate.net/publication/276303432_Evaluation_of_Effectiveness_of_Diode_Laser_System_808_nm_versus_Intense_Pulse_Light_IPL_in_the_Management_of_Unwanted_Hair_A_Split_Face_Comparative_Study
2. Countney E., Goldberg D.J. Clinical Evaluation of Hair Removal Using an 810 nm Diode Laser with a Novel Scanning Device. *Journal of Drugs in Dermatology,* 2016, 15, 11. URL: https://inmodemd.pt/wp-content/uploads/2024/11/PeerRev_Diolaze6m_Goldberg-1.pdf
3. DDC Technologies. Best laser hair removal technology: A deep dive into Alexandrite, Nd:YAG, diode, and IPL systems. *DDC Technologies Insights*, 2025. URL: https://ddctech.com/best-laser-hair-removal-technology-a-deep-dive-into-alexandrite-ndyag-diode-and-ipl-systems/
4. Gan S. D., Graber E. M. Laser hair removal: A review. Dermatologic Surgery, 2013, 39(6), 823-838. DOI: https://doi.org/10.1111/dsu.12116
5. Goldberg D. J. One-year follow-up results of hair removal using an 810 nm diode laser. *Journal of Cosmetic Dermatology*, 2018, 17(5), 775-778. DOI: https://doi.org/10.1111/jocd.12757
6. Grand View Research. U.S. laser hair removal market size & outlook, 2022-2030. *Grand View Research*, 2025. URL: https://www.grandviewresearch.com/horizon/outlook/laser-hair-removal-market/united-states
7. Pall A., Viera Mármol G. Study on the efficacy and safety of a high-power triple wavelength diode laser (810, 940, and 1060 nm) for removing fine and less pigmented facial hair on Asian skin. *Journal of Cosmetic Dermatology*, 2024, 23(4), 1282-1290. DOI: https://doi.org/10.1111/jocd.16129
8. Pall A., & Viera-Mármol G. Triple wavelength and 810 nm diode lasers for hair removal: A clinical and in silico comparative study on Indian skin. *Journal of Cosmetics, Dermatological Sciences and Applications,* 2022, 12, 164-173. URL: https://www.scirp.org/journal/paperinformation?paperid=121699

9. Thomas, M. M., & Houreld, N. N. The ins and outs of laser hair removal: A mini review. *Journal of Cosmetic and Laser Therapy*, 2019, 21(6), 316-322. DOI: https://doi.org/10.1080/14764172.2019.1605449
10. Town G., Brown E.R. Laser and light intervention standards. *Aesthetics*, 2017, 5(1),30-35. URL: https://onlinelasertraining.co.uk/2017/12/15/laser-and-light-intervention-standards/
11. Vaidya T., Hohman M. H., Dinesh Kumar, D. Laser hair removal. In StatPearls. *StatPearls Publishing*. 2023. URL: https://www.ncbi.nlm.nih.gov/books/NBK507861/