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# TECHNOLOGIES OF LASER REMOVAL OF PIGMENT SPOTS WITH PARALLEL LIFTING EFFECT

***Summary.*** *This article discusses modern laser treatment techniques aimed at effectively removing age spots on the skin and achieving a lifting effect. It analyzes the mechanisms of different laser types, their specific features, advantages, and indications for use. Special attention is given to photothermolysis and fractionated effects, which destroy melanin and stimulate new collagen production, helping to even skin tone and improve elasticity. The article presents data on clinical efficacy, safety, possible side effects, and contraindications of the procedures. It also discusses the prospects for combined laser platforms, which allow for personalized treatment and achieve aesthetic results with minimal rehabilitation time. The aim of this work is to systematically gather information about the synergistic effects of lasers in correcting pigmentation and improving skin firmness.*

***Key words:*** *laser removal, lifting effect, melanin, fractional photothermolysis, neocollagenesis, cosmetology, dermatology, aesthetic medicine, age spots, skin rejuvenation, photo rejuvenation.*

**Introduction.** In today's world, aesthetic medicine and cosmetology are rapidly evolving, offering innovative solutions to help preserve youth and beauty. One of the most common dermatological problems patients face is hyperpigmentation - the appearance of age spots from various causes. These spots, which can be freckles, lentigos, melasma, or post-inflammatory hyperpigmentation, are often seen as an aesthetic flaw that can cause discomfort and lower self-esteem.

In parallel with the issue of pigmentation, the challenge of addressing age-related changes to the skin, such as loss of firmness, the appearance of wrinkles, and loss of definition in the facial contours, remains a pressing concern. Until recently, these issues were addressed using separate techniques, which extended the duration of treatment and recovery periods. However, thanks to the development of laser technology, it is now possible not only to target excess melanin but also to stimulate skin rejuvenation simultaneously.

This paper focuses on the analysis of advanced laser technologies for removing pigment spots, which also have a lifting effect. It offers a comprehensive approach to correcting aesthetic defects. We examine the mechanisms of action of different types of lasers, their effectiveness, safety, and potential for use in aesthetic medicine. We emphasize the synergistic potential of these techniques to achieve maximum results with minimal intervention.

**Scientific novelty of the study.** This study explores the mechanisms of laser radiation interaction with skin structures under dual-action conditions – targeting melanin-containing pigmented inclusions while simultaneously stimulating lifting processes. The novelty lies in identifying optimal laser energy parameters that enable selective photothermolysis of pigment cells without damaging surrounding tissues, while concurrently initiating neocollagenesis and remodeling of the dermal matrix. For the first time, the use of combined pulsed energy delivery modes is substantiated, allowing for a synergistic effect in correcting both skin tone and texture.

**Practical significance.** The research findings are valuable for improving laser protocols for pigment spot removal, enhancing treatment efficacy and reducing recovery time. The developed recommendations can be applied by cosmetologists and dermatologists when selecting technologies based on skin phototype and the depth of the defect. The study materials also provide a foundation for the development of new laser systems aimed at comprehensive rejuvenation, as well as for establishing safety standards for combined laser procedures.

**Discussion**. The history of laser pigment spot removal technology is closely linked to the development of laser medicine. The first experiments with lasers in medicine started in the 1960s, soon after the invention of the laser in 1960. At that time, lasers were used with caution and their use was limited due to the relatively low accuracy of the technology and a lack of understanding of how laser radiation interacts with biological tissue [1].

In the 1970s, the first ruby laser devices were introduced, which were used for removing tattoos and some types of age spots. These devices worked on the principle of selective photothermolysis, where light energy of a specific wavelength was absorbed by a target substance (in this case, melanin or the pigment in tattoos), causing it to heat up and break down, with minimal harm to surrounding tissue.

In the 1980s, a revolution occurred with the introduction of Q-switched lasers. These lasers produced short but very powerful pulses, ranging from nanoseconds to microseconds. This significantly increased the selectivity of the treatment, making it possible to target specific areas of the skin more precisely. Q-switched ruby lasers, later followed by neodymium-doped yttrium aluminum garnet (Nd:YAG) and alexandrite lasers, became the "gold standard" for removing age spots and tattoos. These lasers effectively break down melanin, the pigment that gives skin its color, into tiny particles. These particles are then naturally eliminated from the body, minimizing the risk of damaging surrounding tissues.

In the 1990s and 2000s, Q-switched laser technology continued to improve, as did the development of new types of lasers such as diode lasers and Intense Pulsed Light (IPL) systems (Fig. 1). Although IPL is not a true laser, it works on the principle of selective photothermolysis and is widely used to treat pigmented skin conditions. During this time, fractional laser treatments were also developed, creating microscopic damage zones in the skin that stimulate its renewal and collagen production.

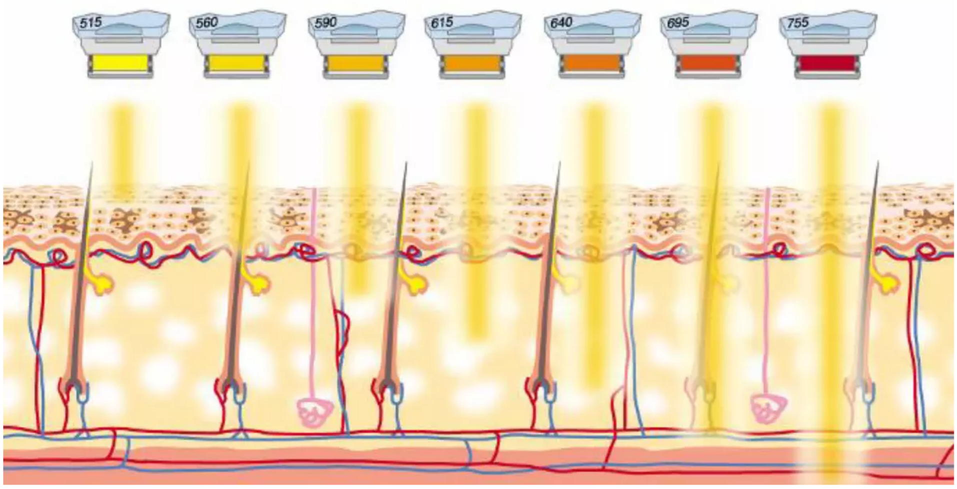


**Fig. 1. Technology of IPL - intense pulsed light**

The current stage of laser development (from the 2010s to the present) has seen the emergence of picosecond lasers. These lasers produce ultrashort pulses, which are thousands of times shorter than those produced by Q-switched lasers are. Picosecond lasers primarily have a photoacoustic effect, generating a strong mechanical wave that shatters pigments into tiny particles, making it more effective at breaking down pigments and reducing the number of treatments needed. This has significantly improved the outcomes of treating complex age spots and multicolor tattoos, as well as opening up new possibilities for using these lasers in comprehensive skin rejuvenation treatments by stimulating collagen production [3].

In parallel with the development of lasers for pigmentation removal, skin-lifting technologies have been constantly improved. Initially, there were ablative CO2 and erbium lasers, which cause controlled damage to the skin layers. Later, non-ablative lasers and radiofrequency (RF) technologies were introduced, which stimulate collagenesis without damaging the surface of the skin (Table 1).

*Table 1*

**Laser technologies in cosmetology**

| № | Name | Characteristic |
|---|---|---|
| 1 | Neodymium Lasers (Nd:YAG) | They are used to remove tattoos and vascular formations. |
| 2 | Alexandrite lasers | They are effective for hair removal and have a wide range of applications. |
| 3 | CO2 lasers | They are used for skin resurfacing (remodeling), as well as for removing scars and wrinkles. |
| 4 | Diode lasers | They are often used for hair removal. |
| 5 | *Application of laser technologies* | |
| 6 | Hair removal: Laser hair removal has become popular due to its effectiveness and long-lasting results. This procedure minimizes the risk of ingrown hairs and skin irritation.<br>Skin rejuvenation: Lasers can help improve skin texture, reduce wrinkles and pigmentation, and increase skin elasticity by stimulating collagen production.<br>Acne and post-acne treatment: Laser treatments can help reduce inflammation, clear clogged pores, and lighten acne scars [3].<br>Tattoo removal: Specialized lasers break down tattoo ink into smaller particles that can then be eliminated from the body.<br>Vascular disease treatment: Lasers are effective at eliminating vascular lesions, such as spider veins, rosacea, and other conditions. | |

With the advent of modern laser systems, such as fractional and picosecond lasers, it has become possible to achieve effective pigmentation removal and a pronounced lifting effect. These lasers stimulate the production of collagen and elastin, realizing the principle of "double action" in a single procedure. This significantly expands the arsenal of aesthetic medicine and offers patients more comprehensive and less invasive solutions.

However, the use of these laser technologies for pigmentation removal with a lifting effect faces several challenges and limitations.

One of the main challenges in pigmentation treatment is finding the right balance between removing pigmentation effectively and achieving a lifting effect. Different types of lasers or settings within the same laser can be optimal for some tasks, but may not be as effective for others. For instance, picosecond lasers excel at destroying pigment, but their lifting effect, while present due to collagen stimulation, may not be as pronounced as that of ablative or more powerful fractional lasers. These latter lasers, while suitable for many types of pigmentation, may have longer rehabilitation periods. Finding the right combination of parameters requires deep knowledge and expertise from the doctor.

The risk of side effects increases when trying to achieve different treatment goals simultaneously. Pigmentation removal carries the risk of post-inflammatory hyper- or hypopigmentation, particularly on darker skin types. Adding a pronounced lifting effect, often achieved through more intense exposure of the dermis, may increase heat damage and the likelihood of adverse events such as swelling, redness, and, in rare cases, scarring. This is particularly true for ablative and certain fractional lasers.

The complexity of treatment protocols and the need for an individualized approach present a challenge. Each patient's skin has unique characteristics, such as phototype, age, skin condition, type of pigmentation (e.g., melasma, freckles, or solar lentigo), and degree of skin elasticity loss. There is no one-size-fits-all solution for addressing these issues simultaneously.

To effectively address these complexities, a thorough assessment is necessary, often involving dermatoscopy. This allows for the development of a personalized treatment plan that may include the use of different wavelengths and modes (e.g., Q-switched, picosecond, or fractional) within a single or multiple procedures. This approach increases the time and cost of treatment, but it allows for better results and reduces the risk of complications. However, incorrect selection of treatment parameters can lead to undesirable outcomes.

The rehabilitation period after treatment may be longer and more intensive than with monotherapy. If mild treatments with minimal downtime are used to remove superficial age spots, a more aggressive approach may be necessary to achieve a significant lifting effect. This can cause peeling, redness, and swelling, which may last from several days to a week. These side effects may be unacceptable to patients who value a rapid recovery.

The high cost of equipment and procedures is a significant barrier. Devices that effectively manage pigmentation and provide lifting are usually complex and require significant investments, which affects the cost of treatments for patients, making them less affordable.

Additionally, patients' expectations can be unrealistic regarding the results of modern technologies. While these technologies can produce impressive results, it is important to communicate with patients about realistic expectations, including the number of treatments required, recovery time, and potential risks, to avoid disappointment.

**Results.** In our view, addressing the challenges related to laser removal of pigment spots while also achieving a lifting effect requires a comprehensive approach that encompasses technological advancements, professional development, and improved communication with patients.

Technological innovation and selective exposure are essential for solving the challenge of balancing effectiveness with side effects. Developing multifunctional laser systems that can operate at multiple wavelengths and in various modes will allow for more precise adaptation to individual patient needs. For instance, the creation of lasers with shorter pulse durations (picoseconds) or hybrid technologies that combine different types of laser or laser and radiofrequency technologies in a single treatment can provide more effective pigment destruction with minimal thermal damage to surrounding tissue, while also stimulating collagen production for a lifting effect. Additionally, improving skin-cooling systems and implementing dynamic temperature monitoring technologies minimizes the risk of burns and other thermal injuries.

To address the challenge of complex protocols and individualized care, further development of diagnostic tools and predictive models is essential. The use of advanced skin diagnostics systems, such as 3D scanners and pigmentation and texture analysis tools, will enable doctors to more precisely determine the type and depth of pigmentation, as well as the condition of collagen fibers and other factors. This, in turn, will lead to the creation of personalized and optimized treatment plans. Additionally, the development of algorithms powered by artificial intelligence and machine learning, which analyze patient data to propose the most suitable treatment options with minimal risks, will be a significant advancement.

Minimizing the risks of side effects and the rehabilitation period can be achieved with more gentle but effective techniques, as well as post-procedural care. So-called "cold" or "non-thermal" lasers that stimulate regeneration rather than cause damage may become part of an integrated approach. The introduction of post-procedure protocols using specialized cosmeceuticals (for example, products with antioxidants, peptides, and growth factors) and hardware procedures (such as LED therapy) can significantly accelerate healing, reduce inflammation, and reduce the risk of post-inflammatory pigmentation. This can also help reduce the period of social maladaptation, making the overall experience more comfortable for patients.

The high cost of medical equipment and procedures is a significant challenge that needs to be addressed. One solution is to scale up technology production and promote competition in the market. With the increasing availability of technology, the cost of devices will decrease, ultimately leading to lower prices for patients. Additionally, the development of more efficient techniques that produce good results in fewer sessions can reduce the overall treatment cost.

Managing patient expectations is an essential part of the process. Specialists should conduct thorough consultations, using visual materials such as before and after photos and 3D models of the expected results, in order to provide the patient with a realistic understanding of potential outcomes, possible risks, and necessary care and recovery times. Clearly communicating that laser treatment is a process and not a one-time miracle will help patients avoid disappointment. Educating them on proper skin care both before and after the procedure, including the use of sunscreen is crucial for maintaining results and preventing complications.

Ultimately, solving these problems is a continuous process that requires collaboration between scientific research, engineering, clinical practice, and education for both professionals and patients.

**Conclusions.** Thus, the successful solution to the challenges associated with laser removal of age spots and a simultaneous lifting effect lies at the intersection of technological advancements, personalized medicine, ethical patient interaction, and interdisciplinary collaboration.

The development and implementation of new generations of intelligent laser systems that can target specific areas while minimizing side effects will be crucial. Equally significant is the transition to personalized treatment plans based on an in-depth analysis of the individual characteristics of each patient's skin, utilizing data obtained through advanced analytical tools, such as artificial intelligence.

Education and professional development for specialists, as well as clear and realistic communication with patients about expected results, potential risks, and necessary care, are essential components of improving the quality and safety of medical procedures.

Long-term and sustainable progress in this area requires continuous investment in research. This will ultimately make advanced aesthetic medicine techniques more accessible, safer, and more effective for a wider range of patients. This will improve their quality of life and satisfaction with treatment outcomes.

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