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Review Article

An Overview of Laser in Dermatology: The Past, the Present and … the Future (?)

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Abstract

The authors discuss a brief history of lasers and their use in dermatology. Although the excellent results achieved by the use of laser in dermatology, this special treatment modality is in continuous evolution. At present, new devices have been under development for the therapy of different kind of diseases, while lasers, already in use, has been changing, in order to be more secure, effective and be useful in many others disorders.

History of Laser

Sixty years after its discovery, in a society increasingly invaded by technologies, it is difficult to imagine how, until a few years ago, the laser was only an empirical technique, an academic study, or a futuristic project, as we can read in Tolstoy's novels.

However, if we want to trace the origins of the laser technology; we have to go back to the first years of XX century when Planck and Einstein's discoveries were laying the scientific basis for the development of the laser.

Max Planck dedicated a lot of time in studying the thermodynamic phenomenon of radiation. Finally, in 1900, maybe in his most important study, he discovered the relationship between energy and frequency of radiation and concluded that energy could be emitted or absorbed only in discrete chunks, named “quanta”.

His theory was an innovative one and inspired new physicists, such as Albert Einstein and other. In 1905, Einstein proposed how light delivers its energy in chunks, which were represented by photons, discrete quantum particles.

Later, in 1916, Einstein introduced the concept of stimulated emission: photons, by interacting with excited atoms or molecules, could stimulate the emission of new photons having the same frequency, phase, polarisation and direction of the first one [1].

Table 1: Milestones in the Lasers development

YEAR	PHYSICIANS	DISCOVERY
1960	Ali Javan, William Bennett Jr. and Donald Herriott	Helium-neon (HeNe) laser
1960	Peter P. Sorokin and Mirek J. Stevenson	Uranium laser
1961	Leo F. Johnson and Kurt Nassau	Neodymium-doped solid state laser
1961	J. McClung and Robert W. Hellwarth	Quality switching (Q- switching) technique to shorten the pulse length to nanoseconds
1962	Sumner Mayburg and Jacques Pankove	Semiconductor Diode Lasers
1964	William Bridges	Argon Laser
1964	Joseph E. Geusic and Richard G. Smith	Nd: YAG (neodymium-doped YAG) laser
1964	Kumar Patel	carbon dioxide laser
1967	Bernard Soffer and Bill McFarland	Dye laser
1970	Basov, V.A. Danilychev and Yu. M. Popov	Excimer laser
1972	Charles H. Henry	Quantum well laser
1976	John M.J. Madey	Free-electron laser (FEL).
1994	Jérôme Faist, Federico Capasso, Deborah L. Sivco, Carlo Sirtori, Albert L. Hutchinson and Alfred Y. Cho	Semiconductor laser that can simultaneously emit light at multiple widely separated wavelengths
1996	Wolfgang Ketterle	Pulsed atom laser
1997	Shuji Nakamura, Steven P. DenBaars and James S. Speck	Gallium-nitride (GaN) laser
2009	Chunlei Guo	Femtosecond pulsed laser

Even if the geniality of the Einstein's quantum theory of radiation, the studies, conducted in the successive decades, did not have a great impact in the scientific world. In 1928, the German Ladenburg and Kopfermann reported evidence about the phenomenon of stimulated emission of radiation [2]. Some years later, Fabrikant proposed how stimulated emission, in a gas discharge, may amplify light [3]; while Purcell and Pound described the stimulated emission of radio waves. In 1953, the American Weber proposed a microwave amplifier that was based on stimulated emission in a paramagnetic solid [4].

Nevertheless, it was only in 1954 that Einstein theory became true in practice. In that year the Americans Townes and Weber, and the Russians Basov and Prokhorov, independently reported about their introduction of MASER ("Microwave Amplification by Stimulated Emission of Radiation"), a special device for generating microwave radiation, using excited ammonia molecules into a resonant cavity [5, 6].

While a burst of microwave maser development followed (e.g. in 1956, Bloembergen developed a microwave solid-state maser) [7], some physicists began thinking about extending the maser principle to higher frequencies.

In 1958, Charles Townes and Arthur Schawalow, in a paper published in Physical Review Letters, showed that masers could be theoretically made to operate in the optical and infrared regions [8].

New experimental studies had been conducted by Townes, Schawalow and by the young physicist Gould.

Finally, the 16th may 1960, Theodore H. Maiman, a physicist at Hughes Research Laboratories in Malibu, constructed the first laser, using a cylinder of synthetic ruby, with the ends silver-coated to make them reflective and able to serve as a Fabry-Perot resonator. Maiman used the photographic flash lamp as the laser's pump source [9].

Only two weeks later, Gould and Schawlow built their ruby lasers.

As often happens with great inventions and discoveries, the laser discovery has been questioned for a long time. In 1964, Townes, Basov and Prokhorov received the Nobel Prize for their studies; and in 1977 Gould was recognised as the father of the laser, who also had the merit of first coined the term "Laser" ("Light Amplification by Stimulated Emission of Radiation").

While the scientific group was discussing those diatribes, the Laser was on, and its technology was in continuous progress. On the other hand, it was the time of the Cold War, and the researches about laser, such as for different technologies, were initially addressed to the military area (e.g. laser guide for a precision bomb, used in Vietnam) [10].

Over the years and with the evolution of technology, despite initial impressions, the laser has become a fundamental, irreplaceable and omnipresent device of modern science. Among the years, new and new laser machines, able to develop different radiation beams, have been built and introduced in commerce (Table 1).

Gradually, the laser has found application in various fields of human activity: from telecommunications to industry, from aeronautics to the space conquest, from photography to the creation of three-dimensional images and computer sphere.

Of course, even the medical field could not remain immune to this phenomenon.

As soon as possible, physicians began testing lasers on the medical practice, especially in the branches, such as ophthalmology, where light sources had been widely used for a long time.

In 1961, the Americans Charles Campbell and Charles Koester treated a patient with a retina tumour with a laser. About a week later, Zweng performed successfully a similar operation [10].

By seventies, lasers had been largely used in many medical areas: Kaplan introduced it in plastic surgery; Aronoff and Jako in otolaryngology; Hofestetter in urology; Kiefhaber and Dwyer in gastroenterology and endoscopy; Bellina in gynecology; Abela in cardiology; Ascher in neurosurgery; Lynn-Power in dentistry; Apfelberg for the treatment of vascular lesions; Chekurov, Oshiro and Trelles in rheumatologic and in traumatology diseases.

Even Dermatology was caught by the new technology.

Laser in Dermatology: the past

In 1963, Leon Goldman, also known as the "father of lasers in medicine", was the first to use the laser in dermatology, thus anticipating an era of unimaginable technological development and innovative therapeutic potential. In his first studies, Goldman reported the effects of Maiman's laser in the selective destruction of cutaneous pigmented structures, like black hairs [11]. He also described the potential use of ruby laser and the more innovative Q-switched device in tattoo removal and the possible treatment of other pigmented lesions, such as nevi and melanomas. Moreover, Goldman investigated the use of Argon laser in the treatment of vascular malformations, and the use of Carbon dioxide laser for the photo-excision of skin lesions [12].

In 1966, Mester, having discovered the positive effects of low-energy red laser on hair growth in rats, decided to use the same system to stimulate the healing of pressure ulcers.

Only a year later, Dougherty experimented with the use of laser in activating photosensitive substances which were able to bind and destroy cancer cells selectively. This was the origin of photodynamic therapy.

In the same period, Goldman was still studying the effects of different lasers in the treatment of dermatological diseases, underlying the importance of protection measures and suggesting the idea of the laser as a diagnostic tool [13]. In 1973, he also introduced the neo dymium: yttrium- aluminium garnet (Nd: YAG) laser in the treatment of vascular lesions.

In the mid-seventies, the Italian Sesti started on investigating non-surgical lasers in wound healing; in 1976, his team treated successfully a case of a pressure sore.

Also, the Italian scientific group had been contaminated by laser technology and in 1979, the first "Italian Society of Laser Medicine and Surgery" was born.

Nevertheless, was only in 1980 that laser therapy has been deeply revolutionized by the selective photo-thermolysis theory, postulated by Rox Anderson and John Parrish: by the use of specific wavelength, we achieve the destruction of specific molecules (or chromophores), allowing better localization of thermal energy and minimization of damage to the surrounding tissue [14].

Only three years later, Oshiro Atsumi described the use of non-surgical lasers and their mechanisms of action. In the same time, Passerella was studying the laser effects on mitochondria.

In 1984, the Food and Drug Administration (FDA) drew the first guidelines for the use of lasers in various vascular and dermatological lesions. From that era, FDA updates them each year.

The eighties are also characterised by the first use of a photo-acoustic laser in the treatment of penis plastic calcifications, and by the introduction of the lasers-sclerotherapy for the management of telangiectasias of the lower limbs.

Finally, the nineties has been characterised by an increasing of study and case reports of laser resurfacing (Gregory and others), laser hair removal and laser rejuvenation.

Table 2: Surgical lasers

CO_2 laser
Erbium laser
Holmium laser

Laser in Dermatology: the present

By the first researches of Goldman, modern dermatology may have at the disposal of a wide range of laser equipment, often very similar to each other, which can treat, many cutaneous diseases with absolute efficacy and safety [15].

Among the dermatologic lasers, the surgical ones are the more commonly used (Tab.2), especially the carbon dioxide laser (CO_2 laser). Due to its specific wavelength (10600 nm) and to its variable nature and duration of output (continuous, pulsed), CO_2 laser may be useful for the treatment of different skin or mucosal diseases (Table 3) [16-18].

Table 3: Clinical indications for CO_2 laser

Seborrheic keratoses
Actinic cheilitis
Actinic keratoses
Epidermal nevi
Scars
Sebaceous adenomas
Balanite xerotica obliterans
Warts
Basal cell epithelioma
Erythroplasia of Queyrat
Stains (melanin)
Neurofibromas
Oral papillomatosis
Resurfacing and Rejuvenation
Rhinophyma (glandular type)
Syringomas
Trichoepitheliomas
Xanthelasmas
Condrodermatite nodular helix
Skin resurfacing and renjuvenation

Also Erbium: YAG laser (wavelength: 2940 nm) is a useful surgical laser, especially for the treatment of superficial cutaneous lesions and skin refreshing (Table 4) [19].

Table 4: Clinical indications for Er:YAG laser

Sebaceous adenomas
Seborrheic keratosis
Acne scars
Favre-Racouchot disease
Xanthelasmas
Neurofibromas
Epidermal nevi
Spots
Resurfacing and Rejuvenation
Rhinophyma (remodelling phase)
Syringomas
Trichoepitheliomas

Others fundamental dermatologic lasers are the vascular ones, maybe the devices which have most benefited from the continuous technological progress. Even if different types of laser are available for the treatment of different vascular lesions (Table 5) [20-22], the DYE laser (Wavelength: 595 nm) and the Nd:YAG (Wavelength: 1064 nm or 532 nm) is the most commonly used because their safe profiles and their wide areas of clinical use.

Finally, there are the dermatologic lasers useful for aesthetic purposes, such as devices for removal of benign pigmented lesions, hair removal, tattoo removal and patients resurfacing (Table 6) [23-26].

Maybe, this area of laser therapy is the one who most had benefit by the introduction of Q-switched devices.

Table 5: Vascular lasers

Laser	Characteristics	Clinical indications
DYE laser	Liquid solution with a particular pigment (Rhodamine) contained in a cylindrical cell	Pws; facial telangiectasias; spider veins; pyogenic granulomas; Rosacea; pecilodermia of Civatte; cutaneous vascular ectasia
Nd: YAG laser	Crystal of aluminium garnet and yttrium doped with neodymium	Telangiectasias of face and legs, hemangioma, spider veins
Argon laser	Argon	Ruby angiomas, angiokeratomas, Kaposi's sarcoma
Alexandrite laser	Alexandrite	Facial telangiectasias
Diode laser	Semiconductor diode	Telangiectasias
Holmium laser	Solid holmium	Telangiectasias
Krypton laser	Krypton gas	Pws
Ruby laser	Bar of synthetic ruby	Telangiectasia
Copper Vapor laser	Steam copper	Facial telangiectasias

Q-switched lasers produce very short pulses (nanoseconds) with high peak powers (megawatts), allowing better and faster clinical results.

Table 6: Dermatological lasers for aesthetics purpose

CLINICAL INDICATION	LASER
Removal of benign pigmented lesions	Nd: YAG (532 nm), Ruby (694 nm), Alexandrite (760 nm), Nd: YAG (1064 nm)
Hair removal	Ruby (694 nm), Alexandrite (755 nm), Diode (800 nm), Nd: YAG (1064 nm)
Tattoo removal	Nd: YAG 1064 nm (black or dark blue tattoo) or 532 nm (red, violet, pink and brown tattoo), Ruby (black, dark blue, green tattoo), Alexandrite (black, blue and green tattoo)
Not ablative resurfacing	DYE laser, CO_2 Q-switched laser

Laser in Dermatology: … the future (?)

Although the excellent results achieved by the use of laser in dermatology, this special treatment modality is in continuous evolution.

At present, new devices have been under development for the therapy of different kind of diseases, while lasers, already in use, has been changing, in order to be more secure, effective and be useful in many others disorders.

Among the first group of devices there is the Xenon Chloride excimer laser (wavelength: 308 nm), useful for the treatment of autoimmune diseases (e.g. psoriasis, vitiligo, alopecia areata) [27-29], and the low-level laser, which is successfully used for the wounds healing [30, 31].

Among the second group, the Nd: YAG laser is an excellent example of how the technological progress may lead to a wider area of clinical uses, such as the lipolysis and the treatment of onychomycosis [32-34].

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