Review paper

LASERS IN DERMATOLOGY: A TECHNICAL AND CLINICAL REVIEW

G. Denardo, A. Doria and G. Trevisan

SUMMARY

In the last ten years, the development of new, better-engineered lasers, has greatly increased their possible clinical applications, which range from the ablation of Port-wine stains and viral warts or other cutaneous lesions, like Jadhasson's nevi sebacei, to nonsurgical applications, like phototoxic therapy in some cutaneous and noncutaneous malignacies.

This article explains the mode of operation and clinical uses of the most common kind of lasers now available in dermatological practice.

KEY WORDS

laser, operation mode, clinical uses

INTRODUCTION

With the development of better-engineered lasers, the applications of lasers in medicine increased. Not only the number of laser operations, but also the number of medical disciplines and specialists that utilize lasers has increased.

Operating the laser is important, but even more important is, the effort to understand and control the interaction between lasers and human tissue.

The Table 1 represents the major characteristics of the lasers that are commonly used in medicine:

MODES OF OPERATION OF MEDICAL LASERS

There are several parameters of the laser radiation which can be varied, depending on the system used and the particular application.

1) ***Wavelength:*** can be tuned in the dye lasers within a range of 20-40 nm using single dye and much broader (up to 400 nm) by exchanging the dye solution. Some lasers can operate in multiline regimen, e.g. Argon (10 lines in the range 440-514 nm), Copper (two lines) or may offer single interchangeable line operation.

Table 1.

LASER	*wavelength (nm)*	*laser medium*	*pulse duration*	*maximum energy (J/pulse)*	*repetition rate (Hz)*	*maximum average power (W)*
Ar-ion	442,514	Gas	CW	———	———	20
Nd:YAG	1064	Solid State	CW	———	———	50
			Q-switched	0.1-1	10-50	———
Copper &	511,578	Metal	20-50 ns	———	10^4-3.10^4	20
Gold vapour	628	vapour	20 ns	———	10^3	1
Ruby	694,3	Solid State	Q-switched	0.1-1	10	———
						20 ns
Dye	330-1000	Liquid	CW	———	———	1
			Pulsed 1-10ns	0.01-0.02	10-50	———
CO2	9600-10600	Gas	CW	———	———	100
			Pulsed	10 μs-10 ms	5	10^3
			waveguide	0.01	5.10^3	50
						1 μs
			pulsed TEA	10	10^3	———
						20 ns
Er:YAG	2940	Solid State	Q-switched	0.02	1-5	———
						20 ns
			free-running	0.2	1-5	———
						200 μs

2) In pulsed Q-switched lasers the pulse duration is normally fixed. The dose of radiation delivered to the patient can be varied by changing the pulse energy, repetition rate or exposure time.

3) In CW systems the power can be easily scaled up within the ratings of the system. Also, the exposure time can normally be adjusted using mechanical or electrical shutters. In some systems, the beam can be scanned along the treated surface using acoustic and optic or galvanometric deflectors.

BASICS OF LASER LIGHT INTERACTION WITH BIOLOGICAL TISSUES

Whatever the involved processes, either a simple re-emission or total destruction of unwanted cells by thermal or photochemical effect, the light interaction with a biological tissue always starts with the absorption of this light. The stronger the absorption is, the shallower is the penetration of the light into tissue. Water, which is the major constituent of the human body, strongly absorbs in the UV (below 200 nm) and in the far IR (above 1300 nm). Aromatic molecules of proteins and nucleic acids posses the highest absorption in the UV range 260-280 nm. As for melanin, most important pigment of the epidermis, it absorbs from UV to near IR. Between 600 and 1300 nm, the light is relatively little attenuated by the different biological tissue, and the body is most transparent at 1000 nm.

Absorption of photons provokes deep modifications in the biological molecules. These strongly depend on the energy and time characteristics of the absorbed light. In general, the induced effects can be divided into the following groups: photothermal, photochemical, photomechanical and photoablative effects.

1) Photothermal: The excited molecules decay through a nonradiative process and the light energy is transformed into heat within the tissues, and rises their temperature. Depending on the reached temperature, heat may lead to vaporization and ablation. Typical applications of photothermal effect are laser hyperthermia, coagulation, welding of tissues and vaporization.

2) Photochemical: The excited molecule enters into complex reactions. The so-called photodynamic effect has been known from the beginning of the century and has been used with the conventional light sources. The usage of lasers has greatly improved its efficiency, since optimum wavelengths could be

used and unwanted processes (i.e. hemoglobin absorption) avoided. The first step of this method consists in injecting into a patient a photosensitizer which has the property of getting attached preferentially onto the tumors. The photosensitized molecules are capable of absorbing laser light with high efficiency and move up to excited states. These molecules decay very rapidly to lower energy states by forming toxic products which kill the malignant cells. Some of these substances have a triple advantage, that is to get attached to the tumor, to reveal its presence by fluorescence and to induce a necrosis by photodynamical processes.

Another type of photochemical processes consists of direct breaking of the intramolecular bonds by high energy (UV) photons. These molecules break into pieces which are ejected in a kind of micro-explosion. This allows the removal of layers of cells nearly one by one.

3) Photomechanical: When absorbed by tissues, laser pulses of short duration (e.g. $< 1\ \mu s$) and relatively high power density, generate stress waves. Many mechanisms that are responsible for these waves depend on the nature of the pulses and tissue.

In transparent materials, the focused laser pulses may give rise to laser-induced breakdown, where free electrons are released in rapidly increasing number and a plasma is produced. The dielectric breakdown is accompanied by high intensity light emission. At the end of the laser pulse, the plasma expands. A shock-wave results, which initially propagates at supersonic speed and may penetrate tens of μm in the liquid. In absorbing tissues, stress waves may be generated at laser power densities much lower than those needed for dielectric breakdown. These waves are caused by thermoelastic effect or ablative recoil. Both effects may considerably modify the tissue behaviour.

4) Photoablative: It's obtained with high-power lasers, whose light is selectively and highly absorbed by the polypeptides in the target tissue (i.e. excimer lasers). The effect is a rupture of the intercellular junctions with a very precise tissue's removal.

TYPES OF LASERS USED IN DERMATOLOGY

GAS LASERS

They consist of a glass tube containing the gas' atoms excited by electrical discharge.

Carbon Dioxide Laser:

It emits in the far infrared (wavelength 10600 nm) and it consists of a glass tube containing a blend of CO_2, Helium and Nitrogen (the proportion is 1:8:8). An air pump creates a vacuum and maintains the correct pressure within the tube. The gas' atoms are excited by an electrical discharge between the two electrodes, within the optical resonator. Helium and Nitrogen enhance the *"population inversion"* phenomenon, while the CO_2, the light emitter, is excited by an energy transfer from the Nitrogen's atoms. Since CO_2 laser light is invisible, each laser incorporates a low power, visible, coaxial Helium-Neon laser, to define the beam path and target area, and the beams are positioned by a micro-manipulator on the laser delivery head (1).

This is a continuous-wave laser, but it can be used in a pulsed (pulse length of 10 ms) or super-pulsed mode (pulse durations from 0.1 to 0.9 ms and peak powers 2 to 10 times the power produced in the continuous-wave mode) (2).

Unlike other types of lasers, the CO_2 laser has not yet been adapted to utilize a fiber-optic delivery system (the power loss is about 70%). At present, the CO_2 laser utilizes an articulated arm with multiple mirrors, which limits the surgeon's flexibility in performing the procedures (3).

The CO_2 laser is considered one of the most powerful lasers, being able to reach peak powers of 80 kW. The most common laser power setting used in skin surgery is between 10 and 25 W, depending it on the skin lesion's type, its thickness, the relative hydration of the targeted tissue and the anatomic site.

Using the CO_2 laser light, the principal chromophore is water. Since skin is approximately 80% water, the infrared CO_2 laser beam can be absorbed with minimal thermal scattering (only 2 to 3%) (4), limiting the thermal damage to 600 μm or less. The cells are disrupted when intracellular water is converted to steam and the contents of the cells are vaporized and carbonized. Immediately after irradiation, there is a coagulation necrosis, extending 0.4 to 0.5 mm into the reticular dermis (5).

The same CO_2 laser can be utilized to vaporize or (4) to cut the tissue, by simply focusing or defocusing the laser beam (3).

Focused or Cutting Mode: In this mode tissue may be excised with the laser by keeping the laser handpiece close to skin surface. A focal point of 0.1

to 0.2 mm can be produced, which allows the tissue excision. A major advantage is that hemostasis is achieved in most cases (but not when using the superpulsed mode). Compared to scalpel excision, there is some thermal damage, and healing of tissue is slightly slower.

The cutting mode may be beneficial when hemostasis is required (blood vessels up to 0.5 mm in diameter are coagulated), when the use of electrosurgery is contraindicated (i.e. pacemakers), in the presence of infected surgical wounds and for the excision of highly vascularized tissue.

It also may be useful in the treatment of large keloids, especially those on the ear lobe.

Defocused or Vaporization Mode: When the CO_2 laser is used to remove superficial cutaneous lesions, the laser beam should be defocused at a distance greater than the focal length of the lens (3), with a spot size of 1 to 2 mm. The penetration depth is just 0.1 mm. In this way a tissue vaporization, with a split of the dermoepidermal junction, is obtained (the so-called *"Laserabration"*).

Major indications are recurrent, hyperkeratotic and painful warts (in particular plantar and periungual lesions), condylomata acuminata (80 to 95% reported successes), epidermal nevi (best for verrucous types) actinic cheilitis. Other possible applications are the treatment of erythroplasia of Queyrat, balanitis xerotica obliterans, adenoma sebaceum, syringomas, trichoepitheliomas, xanthelasmas, neurofibromas and superficial basal cell carcinomas (3). Good results are reported in the management of familial benign chronic pemphigus *(Hailey-Hailey disease)* (6).

CO_2 laser surgery in the defocused mode may sometimes be used in combination with the same laser in the focused mode. Example is the excision of excessive tissue in rinophyma with the focused mode and then the use of the defocused mode to mold the contour to the desired shape.

Recently, a new kind of CO_2 laser, the ultrapulsed type, has been developed. Using an electromechanical shutter, it delivers short pulses (250 μs to 1 ms), so allowing thermal damage of the epidermis and papillary dermis (within a zone less than 100 μm, as opposed to the 400 μm using the continuous mode). In this way, the risk of unwanted scarring is substantially reduced (5).

Argon Laser:

It could be defined a "ion laser", because the gas within the tube is ionized as an effect of the electrical-discharge pumping system. Although the laser beam is delivered in a continuous-wave mode, a "shuttered system could be used. The power of the beam ranges from 1 to 20 W, with a low efficiency. Therefore, this kind of laser requires high energy for the pumping system (about 18 kW per hour), with a great heat production, which has to be wasted by a continuous water flow (about 7.5 to 15 L per min.). The argon laser emits light at six major different wavelengths, from 442 to 514.5 nm, in the blue-green portion of the visible spectrum. 80% of the emission is at 488 and 514.5 nm. The laser light is delivered to the skin surface via flexible quartz optical fibres, usually coupled to the laser beam by a quartz lens.

Fibres comprise a central core of high-quality glass coated with a thin layer of glass at a slightly lower refractive index. Light is transmitted along the fibre by total internal reflection. These fibres range in diameter from 0.1 to 1 mm, according to the laser power and flexibility required (7).

The laser beam diameter on the skin surface varies from 1 to 5 mm, depending on the laser's spot size.

The blue-green light at 488 and 514.5 nm may easily go through tissues having a water component. Selective chromophores are hemoglobin (with absorption peaks at 418, 542 and 577 nm) and melanin (which absorbs in a broader spectrum, ranging, in a decreasing manner, from 200 to 500 nm).

The biological effect on the tissue is the so-called *"selective photothermolysis"*: during the course of treatment there is a transformation of light energy to heat, especially in the tissues where vessels and melanocytes are more numerous. The result is a thermal necrosis of the tissue.

One of the limiting factors is the depth of penetration: thermal injury is usually limited to the upper 1-2 mm of the dermis, so this kind of laser is most effective with lesions located in the superficial papillary dermis. The primary usage, until the recent development of the flashlamp-pumped pulsed dye laser, has been the treatment of vascular lesions. These include port-wine stains (with flattening of the nodular component that often arises within the mature PWS), telangiectasias (best results with the large linear vessels on the face), spider nevi, post-traumatic "red nose syndrome", pyogenic granulomas, cherry angiomas, angiofibromas, angiokeratomas, venous lakes, lymphangiomas and even Kaposi's sarcoma.

Other possible applications are related to pigmented lesions, like lentigines, Ota's nevus, chloasma (5, 14,

25), junctional nevi and also tattoos (especially red and brown-black pigments act as targets for argon laser light, while blue-green pigments act as reflectors rather than absorbers). However, in all these cases, argon laser is not the laser of first choice.

Argon laser may also be useful in the treatment of viral warts, seborrheic keratosis, fibrous-epithelial polypi, keloids. Nonpigmented lesions reported to be successfully removed by argon laser include granuloma faciale, angiolymphoid tumors, adenoma sebaceum, lymphocytoma cutis and other lesions with vascular component. In our experience, treatment of Jadhasson's nevi sebacei is also successful.

The Authors noted a permanent loss of pigmentation in approximately 20% patients and hypertrophic scarring in about 5% cases.

In the treatment of port-wine stains, the argon laser can be used with different techniques:

1. The *"Point by point"* technique, with adjacent but not overlapping spots.
2. The *"Painting"* or *"Stripe"* technique, suggested by Apfelberg, by which parallel strokes are placed on the lesions. The technique is very rapid, but very operator-dependent (8).
3. The *"Dot"* or *"Pointillistic"* method (each spot separated by the adjacent one by 1-2 mm), suggested by Dixon et al. (9).
4. The *"Microspot painting"* technique, suggested by Pickering and Van Gemert. With this technique the operator traces individual blood vessels with a small spot size, equal to the vessel size (16).
5. The *"Random spot"* technique, used by Dixon et al. to treat the upper lip (9).
6. The *"Concentric circle"* technique, suggested by Lee (10) to combine the precision of the pulsed technique with the speed of the stripe technique.

In order to combine speed and precision, are now available robotized scanners, the most famous being the *"Hexascan"*, which delivers nonadjacent spots, until a predetermined size of an hexagonal area (from 3 to 13 mm in size) has been filled (11). These scanners may also be coupled to dye or copper vapour lasers.

Metal Vapour Lasers:

They are the copper vapour laser and the gold vapour laser.

- The *Copper vapour laser* uses vaporized copper, generated from metal bends in a vaporization chamber, as its active medium (12). An electrical-discharge pumping stimulates the emission of extremely brief trains of pulses, which is a unique property of this type of laser. The average emitted power is 2 to 3 W, with trains of 450 to 1500 pulses in rapid succession (frequency of 15 kHz), each one having a duration of 15-20 ns and an average delivery of energy of about 0.2 mJ per pulse (13). The interval between two consecutive pulses is of 70 ns. Because of the very short pulse-length and the very rapid repetition rate, this laser is classified as a "quasi-continuous beam".

This kind of laser emits two harmonic wavelengths: 511 nm (green) and 578 nm (yellow). The system is not tunable, but allows switching from yellow to green wavelength. The laser light is focused onto a 1 mm diameter quartz optic fibre and variable spot size handpieces allow to create beam diameters from less than 0.5 to greater than 5 mm (12). Copper tube replacement is required every 600 hours of operation.

The yellow light matches the ß absorption peak of oxyhemoglobin, while the green light is used to treat brown (melanin) pigmented lesions. Therefore the indications are similar to those instanced with the argon and the 577 nm tunable dye laser.

- The *Gold vapour laser* has the same technical features of the copper vapour laser. It emits an orange-red beam at 628 nm, and at present is under investigation its use with photosensitizing dyes for photodynamic therapy.

DYE LASERS

They consist of a glass cell containing the active medium, which is an organic dye with a strong absorption in the visible wavelengths (i.e. *Rhodamine 6G)*. The organic dye is soaked in a fluid, like ethyl or methyl alcohol. The excitation is obtained by either an argon laser, or a copper vapour laser, or a nitrogen vapour laser (in low-power dye lasers), or by an excimer laser (in high-power dye lasers).

The output wavelength may be varied or tuned by the operator by adjusting the dye (14), or by adjusting the refraction angle of an optical crystal in the laser light path (12). The laser light is delivered through a quartz optical fiber and may vary from approximately 400 to 1000 nm. At present two types of dye lasers are commonly used in clinical applications:

Argon Pumped Tunable Dye Laser: this kind of laser consists of an argon laser, used as an optical energy

to excite rhodamine dye molecules. It emits a yellow-red light, from 577 to 630 nm. The average power is 1 to 3 W only, and the emission is in a continuous fashion.

This could be a limiting factor in clinical applications, so the beam may be gated with an electromechanical shutter, with exposure times from 20 ms to 2 s. The light is delivered via an optical fiber or cable and is coupled to a focusing handpiece that can produce spot sizes from 0.05 to 6 mm.

A simple adjustment allows the use of the pure argon laser beam, without it being passed through the rhodamine dye cell.

Flashlamp Excited Dye Laser: It operates by storing high quantities of energy in a capacitor. A sudden energy release powers a very brief, intense flashlamp burst to excite laser production in the dye. Filters and resonators may be adjusted in series with the optical resonator, to obtain the desired wavelength and pulse duration (usually 300 to 450 μs) (15). The delivery to the tissue surface is obtained by an optical fiber, coupled to a focusing handpiece with a 2, 3, 5 or 7 mm spot size.

The major disadvantage of this type of laser is that the much higher peak energies emitted by a flashlamp to excite the organic rhodamine, cause rapid photodegradation and require fresh dye containers every 5000 pulses, to obtain correct output levels. This is a remarkable maintenance cost.

The yellow light beam at 577 nm, emitted by the dye laser, exactly matches the ß absorption peak of oxyhemoglobin, with a 30% reduction in the absorption rate of melanin. Therefore, a more specific action to vascular lesions is obtained, thus preventing significant scarring or hypo-/ hyperpigmentation after laser treatment of vascular lesions. Immediately after laser exposure, purpura, mild edema and erythematous flare occur, but they resolve within 24 h to several days (18).

Recently 585 nm has been shown to be superior to 577 nm for the treatment of port wine stains and other vascular lesions, because blood absorbs 585 nm laser light approximately 50% less efficiently than it absorbs 577 nm laser light (16). Therefore, in a vascular lesion, the stronger absorbing properties of blood at 577 nm will remove more light thus producing a lower fluence rate and smaller penetration depth than at 585 nm.

The major indication for these lasers is the treatment of hemangiomas and telangiectasias, but, even at 577 nm or at 585 nm laser light emission, these lasers are much less effective for telangiectasias on the lower extremities. A recent report mentions the usefulness of 585 nm pulsed dye laser in the treatment of inflammatory linear verrucous epidermal nevus (17).

Another application of dye lasers is the photodinamic therapy: a phototoxic agent is administered systematically and selectively taken up and retained by malignant cells. Following a clearance period, to allow normal cells to rid themselves of the phototoxin, a red light is delivered and the resulting toxic reaction kills the malignant cells.

The phototoxin is called *Hematoporphirin Derivative (Hpd)*, and the red light may be delivered from a nonlaser source but, more efficiently, from a tunable dye laser at 630 nm. Photodinamic therapy may be used for basal cell carcinomas and squamous cell carcinomas, melanomas, cutaneous metastases, mycosis fungoides, and other cavitary tumors. An undesired side effect is a long-standing generalized photosensitization.

Recently, a new dye laser device for pigmented lesions has been developed: using a coumarin-containing dye as active medium, excited by a high-voltage xenon flashlamp, it produces green light at a wavelength of 500 to 520 nm, with a pulse duration of 300-500 ns and a pulse repetition rate of 1 Hz (12). Since at 510 nm the optimal chromophore is melanin, this kind of laser has proven to be useful in the treatment of superficial pigmented lesions (solar lentigo, cafè-au-lait spots, Becker's nevus). The depth of penetration is 0.25 to 0.5 mm, so dermal pigmented lesions, like Ota's nevus and melasma are usually recalcitrant (5).

SOLID STATE LASERS

Neodymium: YAG Laser (Nd:YAG):

It's a continuous-wave laser which uses as active medium a crystal bar, composed of yttrium, aluminum, garnet, doped with neodymium. The energy for the pumping is optical and derives from a xenon lamp or more recently, from a low power-output diode laser. The emitted laser beam, conducted to the tissue surface via a quartz optic fiber, ranges in the near-infrared light spectrum, with a wavelength of 1064 nm.

This laser light is relatively unaffected by water, as is the CO_2 laser, or hemoglobin, as is the argon laser, and can produce tissue reactions deep of 5-7 mm in the dermis (19). The Nd:YAG laser produces high power outputs, between 0.5 and 95 W or more.

When Nd:YAG laser light encounters tissue, the result is the combination of reflection, absorption and forward scatter, The scattering effect around the incident laser beam causes tissue coagulation and necrosis over a large volume of tissue without its removal.

In the continuous-wave mode of emission, this kind of laser is suitable for special vascular lesions, like deeply located large, bulky cavernous hemangiomas.

Now there is also available the Q-switched version, which utilizes a xenon flashlamp, and the so-called *"KTP Laser"* or *Frequency Doubled Q-switched YAG Laser* (KTP is the acronym for potassium titanyl phosphate).

This laser utilizes a Nd:YAG crystal, producing the 1064 nm wavelength beam generated by a xenon flashlamp. Then, the wavelength is halved by either a frequency-doubling Potassium-titanyl-phosphate crystal, or a photoacoustic method (20). The result is the emission of a 532 nm green laser beam, which is close to the alpha absorption peak of oxyhemoglobin. The Q-switched technique provides a great peak power energy delivery (MW) over much shorter time intervals (10 to 20 ns). In addition, this kind of laser has minimal consumables, since just the flashlamp pumping source has to be replaced. The Q-switched frequency doubled Nd:YAG laser has been shown to cause melanosomes' disruption by overlapping their thermal relaxation time. Therefore, it can be used to treat pigmented lesions, either superficial, like solar lentigo, melasma, post-inflammatory hyperpigmentation, Becker's nevus, nevus spilus and cafè-au-lait spots (at 532 nm), or more deeply penetrating melanocytic lesions, like Ota's nevus (at 1064 nm) (21).

This kind of laser has also shown to be effective in the removal of tattoos, with the 1064 nm laser light fading blue-black pigments, and red-yellow pigments better treated at 532 nm.

Other Mid-Infrared Lasers:

They include the 2010 nm *Thulium:YAG laser*, the 2100 nm *Holmium:YAG laser*, the 2790 nm *Erbium:YSGG laser* and the 2940 nm *Erbium:YAG laser*. Like the Nd:YAG laser, their active medium is solid and the excitation is obtained by a flashlamp. The laser beam may be focused onto the irradiated skin surface either by use of a mirror arm, or a fiber-optic system. All these lasers may be used in a free running mode, with a repetition rate of 1 Hz and a duration of laser emission of 200-250 μs (within this time every single 1 μs-sike succeeds one another) (22). The Er:YSGG laser may also be used in a Q-switched operation mode, providing a pulse-length of 180 ns and repetition rates of up to 10 Hz.

To explain this laser-tissue interaction it is necessary to consider the absorption spectrum of water in the infrared: absorption peaks are found near 2000 nm and at 2940 nm, which coincide with the emission wavelength of the Er:YAG laser.

For this reason, the Er:YAG, but also the Er:YSGG lasers obtain a very precise cut, with a minimal surrounding thermal damage and might become a good alternative to incisional and vaporizational CO_2 laser applications in skin surgery (23).

On the other hand, Ho:YAG and Tm:YAG lasers produce a considerable heat damage, so their use in skin surgery is not advisable, but they might become less destructive alternatives to Nd:YAG surgery in endoscopic applications.

Ruby Laser:

It was the first laser device in clinical practice, used by Maiman since 1960, in a continuous wave mode. With the availability of the Q-switched technique, new interest was rekindled in this laser. This laser utilizes as active medium a ruby crystal, excited by a flashlamp. The result is the emission of short pulses (20-40 ns) of a red light beam at 694 nm, conducted to the tissue surface via articulated mirrors and focused onto a 5-6.5 mm spot size. The frequency of pulse emission is 0.5 Hz (24). This red light is selectively matched by black and blue pigments of amateur and professional tattoos. These pigments are quickly heated up to 300°C and then explode into much smaller particles. It's thought that the very rapid thermal rise causes a mechanical process, in form of a shock-wave (26,27). Then phagocytosis and elimination through epidermis and via lymphatics of the remaining particles occurs. Finally, some pigment is redistributed within the dermis, where it's not clinically identifiable.

There are two limitations in the use of the Q-switched ruby laser for tattoos: blue and black pigments respond best, while yellow, red and green pigments may take many more treatments, if they respond at all. In general, red and green pigments were observed to fade, although not directly irradiated. Such coloration fades when a sorrounding dark pigmented area of the tattoo is irradiated (26). Moreover, more treatments are required for professional tattoos. However, no scarring is noticeable after

laser treatment.

This kind of laser may also be used for the treatment of pigmented lesions, either superficial, like solar lentigines, cafè-au-lait spots and post-inflammatory hyperpigmentation, or dermal located, such as Ota's nevus (25). The results are similar to those obtained with the frequency- doubled Q-switched Nd:YAG laser, but clinically the Q-switched ruby laser appears to provide a better overall treatment response than the KTP laser (21).

Alexandrite Laser:

It's the most recent kind of laser used in dermatology. It utilizes an alexandrite crystal for wavelength propagation. The resulting laser light, emitted in a Q-switched mode, has a 755 nm wavelength, larger than that of the ruby laser (694 nm) and shorter than that of the Nd:YAG laser (1064 nm). The pulsewidth is of 100 ns and the pulse frequency is 1 Hz. The laser beam is delivered to the tissue surface via a fiber-optic cable, with a 3 mm spot size. A helium-neon laser beam, coaxial with the alexandrite one, allows the aiming of the treated site.

The mechanism of action is reported to be basically the same as that of the Q-switched ruby and the Q-switched Nd:YAG lasers. Preliminary studies on the treatment of amateur and professional tattoos (one of the most common applications of this kind of laser) report very good results, with a 95% degree of blanching in all of the treated amateur tattoos and 87% of the professional tattoos (28).

LASER SAFETY

The issue of safety is extremely important when working with lasers.

Optical safety: Of all the body tissues, the retina in the eye is the most vulnerable to laser light. Accidental overexposure may cause severe damage. Special attention should therefore be paid to protect eye against such exposure. All physicians, personnel and patients who may be occasionally exposed to laser beam, must wear appropriate protective goggles. These goggles serve as filters that stop the particular wavelength emitted by the laser and transmit the other colours. The other organ vulnerable to laser injury is the skin. The beam from high-power lasers may cause burns. Moreover, in the case of excimer lasers, there are indications that the radiation at 248 nm may be carcinogenic

Smoke: This may be generated when the laser cuts tissues. The smoke is unpleasant and may also be carcinogenic. It should be evacuated from the operating site using extractor fans when performing laser surgery.

Clothes: Using a CO_2 laser, dry clothes or paper drapes may ignite when exposed to the laser beam. Water absorbs CO_2 laser light energy, and therefore wet drapes are protective. Also the normal skin, surrounding the surgical field must be draped with wet towels. For the same reason, alcohol-containing wipes should not be used, because residual alcohol on the skin surface could ignite if exposed to the CO_2 laser beam.

Electrical safety: Lasers normally have high operating voltages, thus exposing the operators to inherent electrical dangers. However, the power supplies are usually well shielded. The only remaining danger could be during attempts in repairing any occasional malfunctioning. These must be handled by qualified personnel only.

REFERENCES

1. Carruth JAS. Lasers in medicine and surgery. Journal of Medical Engineering & Technology 1984; 8; 4: 161-167.

2. Hobb ER, Bailin PL, Wheeland RG et al. Superpulsed lasers: Minimizing thermal damage with short duration, high irradiance pulses. J Dermatol Surg. Oncol 1987; 13; 9: 955-964.

3. Garden JM, Geronemus RG. Dermatologic laser surgery. J Dermatol Surg Oncol 1990; 16; 2: 156-158.

4. Fairhurst MV, Roenigk RK, Brodland DG. Carbon dioxide laser surgery for skin disease. Mayo Clin Proc 1992; 67: 49-58.

5. Spicer MS, Goldberg DJ. Lasers in dermatology. J Amer Acad Dermatol 1996; 34: 1-25.

6. Don PC, Carney PS, Lynch W et al. Carbon dioxide laserabration: a new approach to management of Familial Benign Chronic Pemphigus (Hailey-Hailey disease). J Dermatol Surg Oncol 1987; 13; 11: 1187-1194.

7. Murray A, Mitchell DC, Wood FM. Lasers in surgery. British J Surg 1992; 79: 21-26.

8. Apfelberg DB, Flores JT, Maser MR. Analysis of complications of argon laser treatment for port wine hemangiomas, with reference to stripe technique. Lasers Surg Med 1983; 2: 357-371.

9. Dixon JA, Hueter S, Rotering R. Hypertrophic scarring in argon laser treatment of port wine stains. Plastic Reconst Surg 1984; 73; 5: 771-779.

10. Lee KJL, Lee KE New technique for the argon laser in the treatment of port wine stains. Laryngoscope 1985; 95: 872-873.

11. Mordon S, Rotteleur G, Brunetaud JM et al. Rationale for automatic scanners in laser treatment of port wine stains. Lasers Surg Med 1993; 13: 113-123.

12. Roenigk RK. Laser: when it is helpful, unequivocal, or simply a marketing tool. Cutis 1994; 53: 201-210.

13. Walker EP, Butler PH, Pickering JW et al. Histology of port wine stains after copper vapour laser treatment. British J Dermatol. 1989; 121: 217-223.

14. Bailin PL. Lasers in dermatology - 1985. J Dermatol Surg Oncol 1985; 11; 3: 328-334.

15. Abd-El-Raheem TA, Hoenleutner U, Landthaler M. Granuloma pyogenicum as a complication of flashlamp-pumped pulsed dye laser. Dermatology 1994; 189: 283-285.

16. Pickering JW, Van Gemert MJC. 585 nm for the laser treatment of port-wine stains: A possible mechanism. Lasers Surg. Med. 1991; 11; 616-618.

17. Alster TS. Inflammatory linear verrucous epidermal nevus: Successful treatment with the 585 nm flashlamp-pumped pulsed dye laser. J Am Acad Dermatol 1994; 31; 3: 513-514.

18. Garden JM, Polla LL, Tan OT. The treatment of port-wine stains by the pulsed dye laser: Analysis of pulse duration and long term therapy. Arch Dermatol 1988; 124: 889-896.

19. Apfelberg DA, Smith T, Lash H et al. Preliminary report on use of the Neodymium:YAG laser in plastic surgery. Lasers Surg Med 1987; 7: 189-198.

20. Kilmer SL, Wheeland RG, Golberg DJ et al. Treatment of epidermal pigmented lesions with the frequency doubled Q-switched Nd:YAG laser. Arch Dermatol 1994; 130: 1515-1519.

21. Tse Y, Levine VJ, McClain SA. The removal of cutaneous pigmented lesions with the Q-switched ruby laser and the Q-switched Neodymium-Yttrium-Aluminum-garnet laser: A comparative study. J Dermatol Surg Oncol 1994; 20: 795-800.

22. Kauffmann R, Hibst R. Pulsed 2.94 μm Erbium: YAG laser skin ablation: Experimental results and first clinical applications. Clin Exper Dermatol 1990; 15: 389-393.

23. Kauffmann R, Hartmann A, Hibst R Cutting and skin-ablative properties of pulsed mid-infrared laser surgery. J Dermatol Surg Oncol 1994; 20: 112-118.

24. Goldberg DJ, Nychay SG. Q-switched ruby laser treatment of nevus of Ota. J Dermatol Surg Oncol 1992; 18: 817-821.

25. Reid WH, Miller ID, Murphy MJ et al. Q-switched ruby laser treatment of tattoos: A 9-year experience. Brit J Plast Surg 1990; 43: 663-669.

26. Lowe NJ, Luftman D, Sawcer D. Q-switched ruby laser: Further observations on treatment of professional tattoos. J Dermatol Surg Oncol 1994; 20: 307-311.

27. Fitzpatrick RE, Goldman MP. Tattoo removal using the Alexandrite laser. Arch Dermatol 1994; 130: 1508-1514.

AUTHORS' ADDRESSES

Gallieno Denardo, Professor of Physics, Director of the Laser's Laboratory, Centre of Theoretical Physics and Dipartimento di Fisica Teorica, University of Trieste, Strada Costiera,11; 34100 Trieste, Italy
Andrea Doria, MD, Clinica Dermatologica, Ospedale di Cattinara, Strada di Fiume, 34149 Trieste, Italy
Giusto Trevisan, MD, professor of dermatology, same address