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CONTINUING MEDICAL EDUCATION

LASERS IN DERMATOLOGY

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The effects of solar radiation were well known to the ancients. Plato's Phaedo contains a passage in which Socrates admonishes that one should not look to the sun during eclipse directly but should view the sun's reflection in water or other such medium.[1] Theophilus Bonetus reported the first central scotoma of retina following solar burn.[2]

The first optical maser (laser as eventually called) was produced by Maiman[3] in 1960 using a ruby crystal producing a 200 μsec pulse of intense monochromatic red light energy having the wave length of 694.3 nm. This pure beam of light was capable of causing small burns of varying intensities.

Laser stands for Light Amplification by the Stimulated Emission of Radiation. Its use in dermatology was explored shortly after Maiman's discovery of ruby maser and since then the search is continuing to find newer techniques with various media, intensity, precision and control.

General considerations

A laser is essentially a device for producing a particularly intense, precisely controllable output of electromagnetic radiation.[4] Collection of atoms or molecules predominantly populate the stable lowest energy level in a ground state. With the increase in temperature of the material a number of molecules are found in upper energy levels having fewer atoms populating it than a lower level. In the optical part of the light spectrum, practically all atoms or molecules are in a ground state. If a light beam of the correct wave length is introduced in the medium, the atoms will absorb the photons of the beam and reach an upper level of excitation and will spontaneously emit photons in random directions before returning to the ground level. In this process, the light beam becomes attenuated.[5]

To have a suitable energy level, a lasing medium has to have a metastable state in which there are more electrons in an excited state than in ground state. This is called population inversion. In such a state of population inversion if a beam of light is introduced, the beam will be amplified because the excited atoms are stimulated to emit photons of precisely the same wave length, phase and direction. To produce a laser, this reaction must take place in an optical cavity which acts as a resonator and the cavity contains the laser medium. The resonant cavity has two mirrors carefully aligned to each other and the laser material is between them. One of the mirrors is made partially reflecting, enabling a part of photons to emerge as laser beam out of the cavity. The continuing chain reaction in the optical cavity increases the number of photons, emission of radiation amplifying the beam further. Thus a coherent beam is built up very quickly; stimulated emission becomes the dominant mechanism of the deexcitation of the atoms and the laser action thus continues. Only waves propagating in closely parallel direction of the laser axis will be greatly amplified emitting highly coherent beam because of the geometric confines of the optical cavity and radiation of stimulated emission in phase

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with the exciting beam In addition, since the energy levels of the laser material are narrow and well defined, the laser beam is monochromatic.

Properties of laser beam

The laser beam as a unique source of radiation is dependant on its following qualities:[6]

(a) High intensity—probably producing thermal effects.

(b) Coherence—facilitates directing the radiation through optical paths.

(c) Monochromaticity--helps in selecting chromophores from within complex biologic media.

(d) Very short pulses.

Though they are individual attributes, they are collective and interrelated.

Types of lasers

Clinically or experimentally many different types of lasers have been used :

(1) Optically pumped pulsed laser : Ruby, neodymium-doped glass laser, neodymium-YAG laser and flash lamp-pumped dye laser or tunable laser.

(2) Gas lasers : Argon laser, Carbon dioxide laser, Krypton laser and Helium-neon (He-Ne) laser.

(3) Ultraviolet laser.

Modes of operation

Operation of a particular laser depends on laser material, mode of excitation and configuration used. Following are the modes of operation of the lasers :

(1) Continuous-wave (CW) operation

In this mode, the atoms or molecules are continuously excited to upper energy levels and then stimulated down thus emitting continuous radiation. Argon, krypton, neodymium-YAG and carbon dioxide lasers operate in this way.

(2) Pulsed operation

This type of operation is obtained when the laser material is pumped with flash lamps and the output results into a train of random pulses grouped closely together and lasting for milliseconds only. Ruby and neodymium-doped glass laser operate by this mode.

(3) Q-switched operation

'Q' stands for quality factor of the resonant cavity. This gives pulses of very short duration and high power.

(4) Mode-locked operation

The output of this operation consists of a series of very short pulses and desirable temporal variation of the laser output can be obtained.

Details of the various operations are beyond the scope of this review.

Photon-tissue interactions

Extremely complex molecules maintaining their vital activity in specific configurations and ambient conditions are part of biologic system.[5] Photons excite different interaction with biologic material depending on the photon wave length. In the UV region, the photons lead to disruption or alteration of DNA and RNA into abiotic forms resulting in cell death. In the visible spectrum the photons can lead to either thermal damage or photochemical reaction. Photons in infrared or longer wave lengths also cause thermal interactions. Thus, the end result of interaction of radiation with tissue can be : (a) Cell death, (b) Photochemical changes, (c) Thermal damage e.g. photocoagulation and tissue damage, (d) Vaporization leading to tissue separation by way of formation of steam of tissue water and shock waves.

The advantages of use of laser in general are predictable and specific target tissue response, minimal energy requirement for desired power selection, high beam photon flux density, pulsing capabilities and precise focussing potential.

Following lasers have been used in dermatology experimentally or clinically :

Table I. Laser sources in dermatology.

Laser system	Wave lengths	References
Ruby laser	694	7, 8, 9
Argon laser	488, 514	10, 11, 12, 13, 14, 15, 16, 17, 18
Carbon dioxide laser	10600	19, 20, 21, 22, 23, 24
Neodymium-YAG laser	1060	25, 26, 27, 28, 29
Tunable dye laser	540, 577	30, 31
Ultraviolet laser	193, 248	32, 33

Therapeutic uses in dermatology

The discovery of laser in 1960[3] opened vast vistas of its potential use in all fields of medicine. Controllable depth penetration, precise focussing capabilities of the monochromatic, coherent beam and high photon energy density were the properties of lasers initiating many a dermatologist into enthusiastic exploration of their uses in dermatology. In dermatology the lasers are used largely as a tool for controlled destruction of tissue taking advantage of the properties of the lasers like precision and control of destruction, absence of bleeding from the microcirculation and minimal damage to surrounding tissue.

Table II. Advantages and disadvantages of lasers.[1,4,32,33]

Laser	Advantages	Disadvantages
Ruby laser	1. Pigment epithelial absorption (melanin) primarily.	1. Short, pulsed exposures.
	2. Little absorption by haemoglobin.	2. Minimal absorption by haemoglobin.
	3. Short, pulsed exposures with minimal thermal diffusion.	3. Limited coagulation ability.
	4. Minimal discomfort and damage.	4. Small coagulation incapability.
Argon laser	1. Highly absorbed by haemoglobin and melanin.	1. Penetration of large vascular abnormalities possibly minimal.
	2. Extremely large coagulation range possible.	2. Chances of scarring in 5%.[4]
	3. Large range of exposures available.	3. Power output relatively low.
	4. High power density available.	
	5. Excellent variable delivery system.	
CO_2 laser	1. Useful for patients with bleeding tendencies and vascular sites.	1. Relatively powerful.
	2. Precision of damage.	2. Pulsed mode expensive.
	3. Lack of post operative inflammation.	3. Difficult instrument to operate and maintain.
	4. Post operative pain and discomfort rare.	4. Needs much training and experience.
	5. Instant vaporization of cells.	
	6. Useful in producing superficial epidermal and papillary dermal necrosis.	
Neodymium-YAG laser	1. Relatively deep tissue penetration.	1. No colour specificity in its effect.
	2. High power density/high photon flux.	2. High absorption.
	3. Low thermal diffusion.	3. Vascular rupture potential in short exposures.
	4. Short exposure times.	4. Hydrodynamic shock wave effect uncertain.
	5. Cutting and lysis of transparent tissue.	
Ultraviolet laser	1. Tissue removal clean and precise.	1. Mutagenic hazards uncertain.
	2. Thermal damage to surrounding tissue minimal.	2. Limited experience.

The therapeutic effects of lasers can be biological, photochemical or thermal. While much work is needed to ascertain the usefulness of the biologic effects, dermatologic applications utilise mostly the thermal effects and less so the photochemical reactions. Lasers can be used for following applications:[6]

(a) Excision and vaporisation.
(b) Coagulation necrosis.
(c) Photochemical cell necrosis.
(d) Superficial burn (Slough and bury).

The dermatologist only takes therapeutic benefit of the photophysical insult inflicted by the lasers to the tissue, but the end cosmetic result depends on the photobiologic host response.

The effect of laser on the tissue depends on a number of factors which are interdependant. These are the wave length, the power per unit area, the type and length of exposure and the optical characteristics of the skin.

Different laser sources used in dermatology with the relevant references are shown in table I. However, the dermatologic disorders in which different lasers have been used are summarised here for the sake of convenience.

Laser	Indications
Ruby	Pigmented nevi, blue/black tattoos.
Argon	Angiomas, telangiectasia, angio-fibromas and spider nevi. Benign pigmented lesions. Tattoos.
Carbon-di-oxide	Actinic cheilitis Angioma (port-wine stain) Dystrophic painful nail Epidermal nevus Lymphangioma Rhinophyma Tattoo Superficial basal cell epithelioma, syiingoma, trichoepithelioma, xanthelasma, plaque psoriasis.
Neodymium-YAG	Angiomas Melanoma Keloids Warts
Tunable dye	Port wine stain

Recently Lane et al[32] used pulsed ultraviolet laser irradiation from argon-fluoride and krypton fluoride laser to ablate the skin. They obtained clean incision with minimal thermal damage. However, further studies are indicated in this particular field to evaluate the risks of mutation.[33] More recently Becassy and Astedt[34] used high energy CO_2 laser for treating circumscribed plaque psoriasis in three patients and during 3.5 years follow-up period all remained free of psoriasis. Though costly, this appears to be a very effective and simple vaporization technique using laser in intractable plaque psoriasis.

Olbricht et al[35] surveyed a selected group of dermatologists and plastic surgeons to review the complications of the use of argon and carbon dioxide lasers. Hypertrophic scarring was the most frequent complication and less frequent were unexpected pigmentary change, pain, haemorrhage, prolonged healing, infection and atrophic scarring. Conjunctivitis, inability to suntan and exacerbation of acne were rare. No death, ocular damage or carcinogenesis was reported. Total depigmentation and thread like scarring occurred in areas treated with argon laser in a female with extensive post-solar poikiloderma of the neck.[36]

Use of lasers in dermatology is a relatively new addition in our armamentarium, arming the dermatologist with capabilities of striking at the target tissue with precision by way of inflicting physical insult, but improved cosmetic outcome remains a matter of host tissue response.

Their application undoubtedly has shown promising results. One must await proper evaluation of the laser research, new laser media, new delivery systems, understanding of laser-tissue interaction and patient acceptability.

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