Essay

Biological Effects of Laser

By

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MbBch

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Abstract

The effect of laser on biological tissue is varied. It depends on several parameters, most important of which, are the wavelength; the pulse duration; and the energy fluence.

Treating dermatologic disease with laser requires thorough understanding of the laser physics in addition to understanding the complications and hazards of laser therapy.

Keywords: Laser, Biological effects, Pulsed dye, Er:YAG, carbon dioxide, Ruby, Alexandrite, Nd:YAG, Diode, Excimer.

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Introduction and Aim of Work

The biological effects of laser are varied depending on the laser system. The principle behind the biological actions is the same in all types, but the response of the tissue to the various wavelengths and pulse durations is quite different.

In this assays we tried to compile and summarize the biological effects of all types of laser. Doing that is almost impossible, because of the enormous amount of literature and the very large number of laser system in use. So I tried summarizing the effects of the well known laser system with special emphasis on the common systems used in Egypt.

The biological effects are put within the context of the assay describing along with it some clinical effects and side effects as well as some statistics so that the reader can correlate between the biological effects and the clinical practice.

For the sake of simplification, the biological effects were presented in italics to facilitate reading.

History of Laser

LASER is an acronym for Light Amplification by Stimulated Emission of Radiation (**Acland** and **Barlow**, 2000).

The theoretical concept of laser light was first proposed by Albert Einstein, who in the year 1917 published the theoretical concepts and principles of stimulated emission of radiation as part of his quantum theory.

In the year 1955, **Townes** and **Gordon** were the first to amplify radiant energy through stimulated emission. They used ammonia gas as an optical medium to generate coherent microwave radiant energy from a device known as MASER, for Microwave Amplification by stimulated emission of radiation.

Ruby laser was the first true operational laser system. It was developed in 1960 by **Maiman**. He was working for the Hughes Corporation at that time and was able to generate a beam of coherent red light by stimulating a ruby crystal with microwave energy.

Second came the helium-neon (He-Ne) laser that was developed by **Javan** in 1961 and on the same year **Johnson** developed the neodymium:yttrium-aluminum-garnet (Nd:YAG). The Argon laser followed in 1962 by **Bennett** and then the carbon dioxide laser by **Patle** in 1964

(**Bromberg**, 1991). Soon these devices became available and they were rapidly accepted by the medical community (**Wheeland et al**., 2000).

The theory of selective photothermolysis that was proposed by **Anderson** and **Parrish** in 1983 was a big breakthrough in the application of lasers in dermatology. The ability to destroy a specific target chromophore such as hemoglobin or melanin while leaving other skin structures intact allowed the treatment of superficial vascular malformations and benign pigmented lesions. This was the first idea for a laser to be developed with a specific indication in mind rather than building a laser first and then trying it out on various lesions (**Hurza**, 1998).

Laser physics

The electromagnetic spectrum spans a very large range of wavelengths from long radio waves to ultra short gamma rays. The visible light is a very small portion of this spectrum occupying less than 0.1% of it (Fig. 1) (Fontana Medical Laser Report, Application Handbook, 1998).

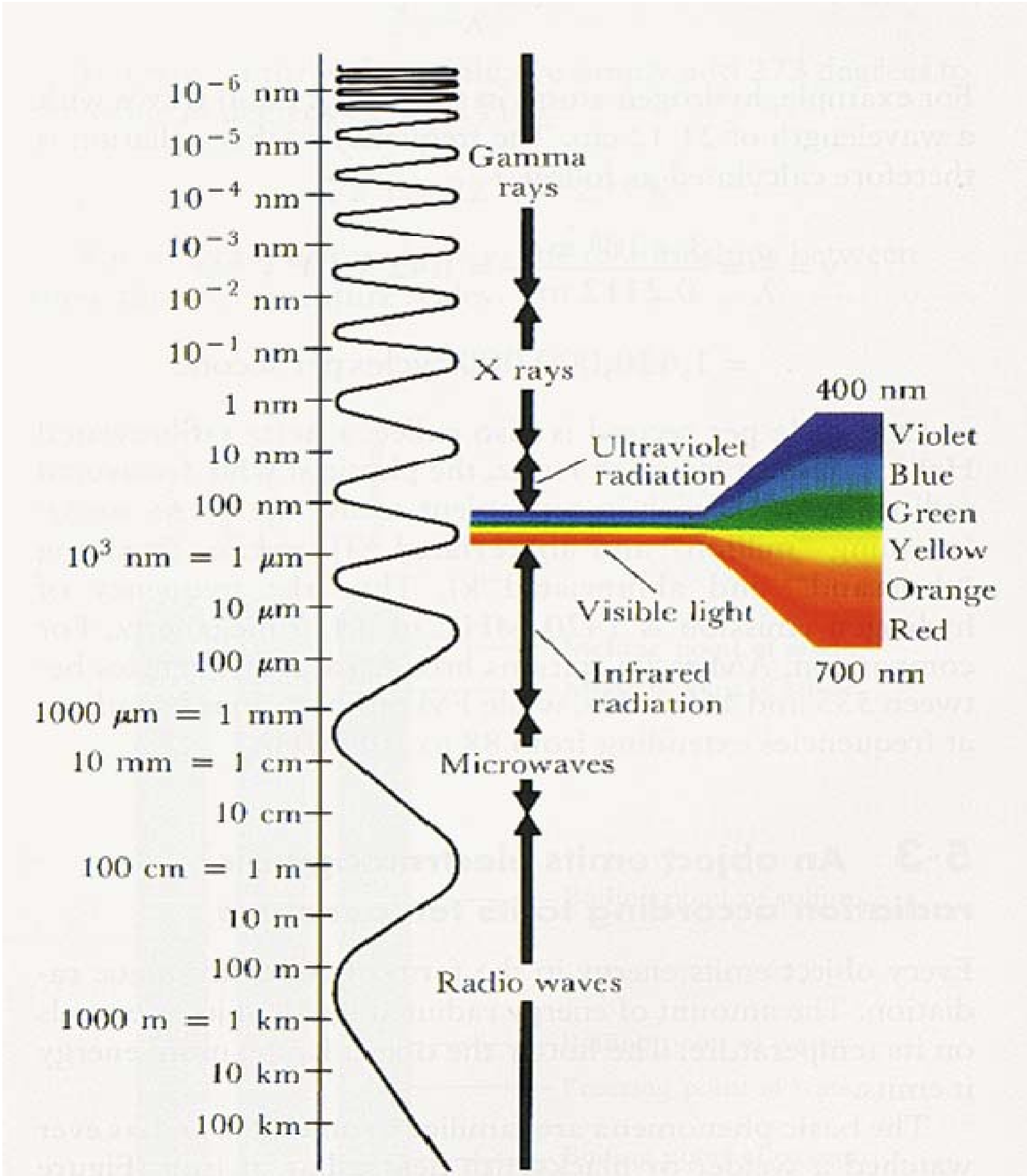

Fig (1) Electromagnetic spectrum

The visible light spectrum is surrounded by the ultraviolet light and the infra red light which have shorter and longer wavelengths respectively as compared to the visible light.

Lasers can theoretically produce light at any point on this spectrum but in practice common lasers in use today are infrared, ultraviolet or visible light (**Absten**, 1992).

The electromagnetic waves have four characteristic items which are namely:

1. **Wavelength** (λ): It Is the distance between two successive crests of the wave. The color of the light is determined by its wavelength measured in nanometers "ηm" 10^{-9}m. Shorter wavelengths require more energy to be produced. The wavelength is the character that determines the absorption of the wave by the tissues (**Carruth**, 1986).
2. **Amplitude** (a): it is the power of the wave measured by the height of the wave.
3. **Velocity** (v): the velocity of electromagnetic waves in general is constant and it equals approximately 300,000 km/second.
4. **Frequency** (f): this is the numbers of waves per second.

The velocity of the wave is the product of frequency and wavelength. And since velocity is constant thus frequency and wavelength are inversely proportional (**Absten**, 1992).

Properties of laser:

There are 3 characteristic differences between laser and ordinary light, namely, Monochromaticity, Collimation and Coherence.

1. **Monochromaticity**: the laser light is monochromatic unlike ordinary light, which is polychromatic. This means that the output of the laser system is in the form of waves,which all have the same wavelength (Fig. 2) (**Bailin**, 1985).

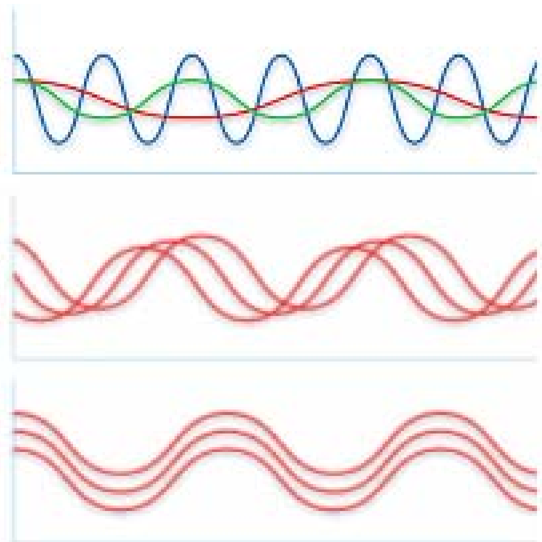

Fig (2) Monochromaticity

2. **Collimation**: this can also be referred to as nondivergence. The laser light does not diverge as it travels t0hrough space and thus it remains a directed beam and does not lose its intensity (**Bailin**, 1985). This allows laser systems to have small spot sizes (Fig. 3) (**Mainster**, 1989).

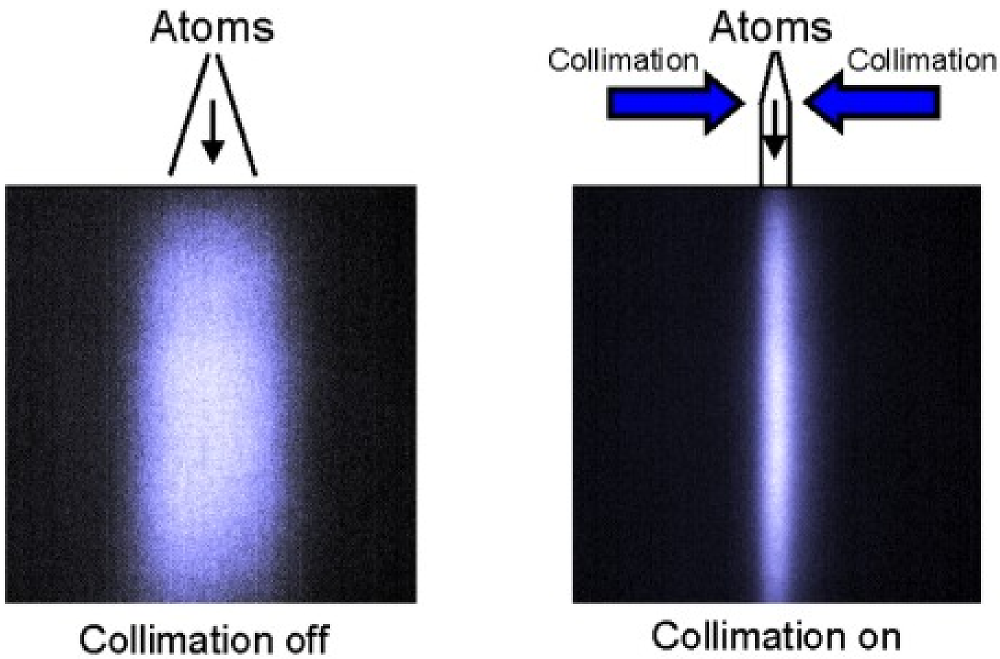

Fig (3) Collimation

3. **Coherence**: **Sigelman** (1984) clarified that coherence is achieved when the oscillation of the waves of electromagnetic radiation in the laser light occur simultaneously in both time and space. Coherence is the combination of the two previous points. This means that the alignment of the waves as they travel through space is uniform, i.e. the peak of each wave begins at the same time (Fig. 4) (**Absten**, 1992).

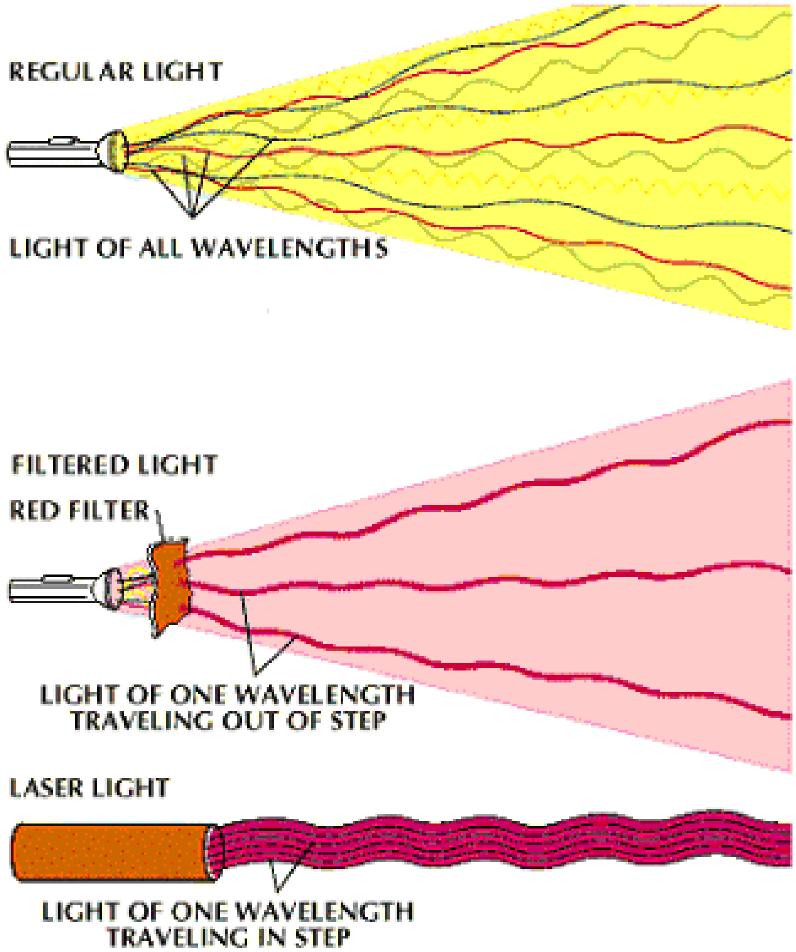

Fig (4) Coherence

The lasing process

An atom is composed of a nucleus and electrons orbiting around it in multiple levels. The further the level of electron from the nucleus the higher is the energy level. This is called the quantum mechanism (**Hurza**, 1998).

Light is made up of photons. A photon is produced when an electron drops from a higher to a lower level of energy. In a reverse fashion an atom