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Medical Laser Application 21 (2006) 99–108
Medical Laser Application
www.elsevier.de/mla

The medical laser

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Abstract

The history and the main fundamentals of lasers in medicine are summarized in this article.

The application of light for materials processing was first described by Aristophanes in his comedy "The Clouds" 423 B.C. In the 2500 years, or so, that have passed until the laser was invented, light had been used both for materials processing and for medical purposes in many ways. But only the laser has paved the way for widespread therapeutic use of optical radiation.

Supported by numerous medical technology companies, Prof. Dr.-Ing. G. J. Müller founded the LMZ (Laser-Medizin-Zentrum gGmbH, Berlin), now LMTB (Laser- und Medizin-Technologie GmbH, Berlin) in 1985. Dr. H.-P. Berlien had been hired as Medical Director in this internationally renowned centre of competence for laser medicine. Dipl.-Ing. Clemens Scholz was among the first postgraduate students – he is now member of the board of WOM (World of Medicine).

The German version of this paper was published in Umschan 1986;(4):233–240.

Keywords: Lasers in medicine; Materials processing; Optical power; Average power; Pulse energy; Repetition rate; Biostimulation; Photocoagulation; Optical breakdown; Laser safety

Introduction

The application of light for materials processing was first described by Aristophanes in his comedy "The Clouds" 423 B.C. In the 2500 years, or so, that have passed until the laser was invented, light had been used both for materials processing and for medical purposes in many ways. But only the laser has paved the way for widespread therapeutic use of optical radiation.

The history of the medical laser is the history of the laser as such. When *Maiman* had found the laser effect in 1960 it was very difficult for him to have this discovery published in a renowned journal because nobody seemed to be aware of its importance. Due to the physical particularities of the laser effect, however, it took not very long until the wide variety of possible applications had been realized. The ruby laser was medically used first by *Campbell* in ophthalmology in 1961 and by *Goldmann* in dermatology in 1963. While in ophthalmology lasers, especially the argon ion laser, have become widely accepted and established as a therapeutic tool, its general success in other medical disciplines is still outstanding. A physician from Budapest/Hungary by the name of *Mester* tried biostimulation initially by using a ruby laser in 1964 and later a weak helium neon laser in 1974. Another system, which has gained access to other medical disciplines, is the carbon dioxide (CO_2) laser that was originally called light scalpel. Early experiments were made by *Polanyi* and *Kaplan* in 1965 and 1967,

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1615-1615/$ - see front matter © 2006 Elsevier GmbH. All rights reserved.
doi:10.1016/j.mla.2006.03.004

respectively. Thereafter, the CO_2 laser slowly but surely gained ground in the different fields of medicine. The argon laser, but above all the neodymium YAG laser, became interesting for wide medical application not before it became possible to lock them into fibres. In 1971, *Nath* developed a fibre, which he and *Kiefhaber* first employed in 1973 through endoscopes in the gastrointestinal tract in animal experiments. From then on progress was quickly made. In 1975 *Dwyer* in the United States and *Frühmorgen* in Erlangen/Germany used an argon laser to stop gastrorrhagia in patients. Late in 1975 *Kiefhaber* used a neodymium YAG laser for the same purpose. In 1976, *Hofstetter* used the laser for the first time in urology, and in 1979 *Choy* filed an application for a patent for opening sclerotic arteries with a laser. Once the hematoporphyrin derivate was discovered in 1960, *Diamond* was the first to apply this substance for photodynamic therapy in 1972, while *Dougerty* standardized these therapeutic applications to large extent in 1975.

Referring to the pulsed laser systems, q-switching and mode locking was used for the first time by *Fankhauser* and *Aron-Rosa* in ophthalmology. In the same discipline, the excimer laser was introduced by *Trokel* in 1983.

However, the medical laser is still in its infancy although it has many advantages which are described hereinafter.

Basic physics

The conventional light sources, which are applied in traditional cases of light therapy, are to laser systems like an erratic discharger to a radio transmitter. As perfect light transmitters, laser systems within the terahertz and petahertz ranges are the direct analogue to the radio transmitter in the megahertz range. LASER is the acronym for *L*ight *A*mplification by *S*timulated *E*mission of *R*adiation. Although, the induced emission postulated by *Einstein* is rudimentarily existing in every luminous phenomenon of matter as an effect, it can be made dominant in selected materials, only. By the way, human breath consisting of CO_2, nitrogen and steam would be suitable as laser medium for a weak CO_2 laser, and some brands of dry gin have already been used for lasing because they contain a sufficient quantity of blue fluorescent quinine.

Just as in medicine, where specific instruments are used for various operations, there are various medical laser systems for different medical clinical fields of application, depending on the tissue spectra (Fig. 1). These systems differ by their emission wavelength, expressed in microns or nanometers, starting in the UV range at a wavelength of ca. 0.2 μm and extending to

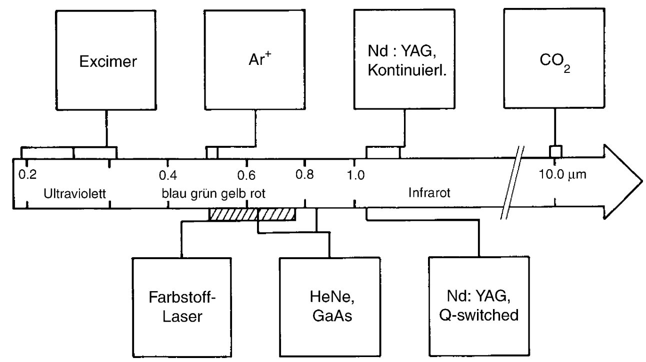

Fig. 1. Laser systems of various emission wavelengths.

the infrared up to ca. 10 μm. Since most laser systems depend on a narrow spectral transition of electrons, they cannot be tuned as simply as radio transmitters, except for dye lasers, vibronic and free electron lasers and parametric oscillators. Although, there are some gas lasers which offer several wavelengths depending on the selected medium, these wavelengths cannot be shifted. Moreover, laser systems differ by their technical and physical configuration in terms of structural arrangement and time behaviour of the laser beam.

To understand why such big a variety of laser systems is necessary let us outline some basic physics.

Contrary to the thermal lightwave the laser light displays three important characteristics. Its radiation is

- *coherent*, i.e. all the wave trains are exactly in phase, in time as well as in space.
- *well collimated*, i.e. the radiation beam is almost parallel (showing a low divergence)
- *monochromatic*, i.e. a narrow spectral band of high spectral intensity is emitted.

These three characteristics permit the good focusing ability required to obtain high-energy densities and, consequently, precision working with a beam of smallest cross-sectional area. Optimum focusing of a laser essentially depends on the intensity profile of its beam: The intensity should have its maximum in the optical axis and steadily decline to the outside (so-called Gaussian profile). The profile of the bundle of rays is directly connected with the mode of the lasers as such. While in acoustics different vibrations (Chladni figures) become visible by the stroke of a violin bow, the light column between the two mirrors of a laser system has many modes, as well, which are referred here to as TEM (being the acronym for *T*ransverse *E*lectromagnetic *M*ode) and two indices: TEM_{00} stands for the fundamental mode delivering the required Gaussian profile which produces the minimum focal spot (Fig. 2a). By means of constructional measures it is tried to achieve that laser systems work exclusively in this mode. The