ejpmr, 2024, 11(6), 716-727

SJIF Impact Factor 7.065

EUROPEAN JOURNAL OF PHARMACEUTICAL AND MEDICAL RESEARCH
www.ejpmr.com

Review Article
ISSN 2394-3211
EJPMR

LASER APPLICATION IN MEDICAL, CHEMICAL AND ENVIRONMENT

Halaa Raid Faiq*, Omer Muhammad Aziz, Nour Mohammed Ibrahim, Nour kamel Abdel Nabi, Shereen Jomaa Kalefa and Khetaam Adnan Odaa

***Corresponding Author: Halaa Raid Faiq**

Email Id: oaliraqy160@gmail.com

Article Received on 21/04/2024 **Article Revised on 11/05/2024** **Article Accepted on 01/06/2024**

ABSTRACT

In fifty years, laser technology has made great progress, and its many applications makeit essential in everyday life. However, this technology is still open to numerous developments. Across multiple applications, there is particular focus in the field of medicine, for diagnosis for tailored therapies, and as a research tool in biology. Whereas its use is now well-demonstrated in ophthalmologic and dermatologic treatments, and surgery, one of the most fascinating aspects of laser technology in the field of biology emerged in the late 1990s with the development of devices able to perform fine dissections of biological tissues using a laser beam. Lasers have a wide and growing range of applications in medicine. In this paper medical applications of Lasers are discussed. Lasers are wonderful devices with enormous application potential. Lasers have a wide and growing range of applications in medicine. The use of lasers in medical diagnosis and treatments is known as laser medicine. Their increasing use in medicine is driven by new technology and a better understanding of the interaction of laser light with living tissue. Being faster and less invasive with high precision, lasers have penetrated most medical disciplines during the past half century, including dermatology, ophthalmology, dentistry, otolaryngology, gastroenterology, urology, gynecology, cardiology, neurosurgery and orthopedics. This article gives an insight into the basic principle, characteristics and medical applications of lasers. Laser spectroscopy provides many possibilities for multidisciplinary applications in environmental monitoring, in the ecological field, for food safety investigations, and in biomedicine. The paper gives several examples of the power of multi-disciplinary applications of laser spectroscopy as pursued in our research group. The studies utilize mostly similar and widely applicable spectroscopic approaches. Air pollution and vegetation monitoring by lidar techniques, as well as agricultural pest insect monitoring and classification by elastic scattering and fluorescence spectroscopy are described. Biomedical aspects include food safety applications and medical diagnostics of sinusitis and otitis, with strong connection to the abatement of antibiotics resistance development.

INTRODUCTION

Laser is a powerful source of light having extraordinary properties which are not found in the normal light sources like tungsten lamps, mercury lamps, etc. The unique property of laser is that its light waves travel very long distances with e very little divergence. In the medical field, lasers are diagnostic and therapeutic instruments that offer a whole range of solutions. The laser which enables for greater surgical precision is less invasive and promotes healing time or cure. This technique is generally much less traumatic than traditional surgical techniques. The most outstanding invention of the 20th century is the laser. The word LASER is an acronym for “Light Amplification by Stimulated Emission of Radiation”. A laser is a device that uses energy to transmit light at a specified wavelength and amplifies that light by producing a very narrow beam of radiation.[1] Laser is very much different from the traditional light sources and it is not used for illumination. The difference between ordinary light and laser light is like the difference between ripples in your bathtub and huge waves on the sea. It comes in sizes ranging from approximately one-tenth the diameter of a human hair to the size of a very large building, in powers ranging from 10-9 to 1020 W, and in wavelengths ranging from the microwave to soft X-ray spectral regions with corresponding frequencies from 1011 to 1017 Hz .In addition, lasers have very high pulse energies i.e. up to 104 J with very short pulse durations i.e. 10-16 s. The laser produces a very narrow beam of radiation. The emission generally covers an extremely limited range of visible, infrared and ultraviolet wavelengths.

In 1917, Albert Einstein laid the foundation for laser technology, when he predicted the phenomenon of "stimulated emission", which is fundamental tothe operation of all lasers. In 1939, Valentin Fabricant theorized the use of stimulated emission to amplify radiation. Then Charles Townes, Nikolay Basov, and

Alexander Prokhorov developed the quantum theory of stimulated emission and demonstrated stimulated emission of microwaves in 1950.[2] They later received the Nobel Prize in Physics for this ground-breaking work. In 1959, Gordon Gould proposed that stimulated emission can be used to amplify light. He described an optical resonator that could produce a narrow beam of coherent light. He called it a LASER. Theodore Maiman built the first working prototype of a laser in 1960. He used a synthetic ruby as the active medium in this laser which emits a deep red beam of light with a wavelength of 694.3 nm. Thereafter a variety of lasers with highly varied characteristics have been developed which are being used in many applications. Lasers are remarkable devices. When the principle of laser technology became known, everything suddenly proceeded rapidly in terms of development. Particularly in the field of medicine, it became the "beam that heals" and has been utilized in nearly every discipline of medicine, in diagnosis, therapy, surgery and medical instrumentation. The purpose of this article is to give the general principle of laser along with their properties and components and medical applications of lasers.[3]

The Navy currently uses, and is continuing to develop, laser technology applied in an underwater marine environment. This technology primarily is used for communication, surveillance, and mine detection. As new technologies are transferred to the Fleet through the acquisitions process, it is necessary to identify and mitigate environmental, safety, and occupational health (ESOH) risks associated with the emerging systems. ESOH risks need to be addressed in compliance documentation related to PESHEs in the acquisition process, and National Environmental Protection Act(NEPA) compliance, which includes preparing EISs for proposed Navy actions. Currently, EISs use general information to assess the risk of laser activity in the marine environment. Scientifically defendable technical data are needed to develop Navy-wide environmental policies for performing EISs with laser activity in marine environments.

LASER is an acronym for Light Amplification by Stimulated Emission of Radiation which describes the theory of laser operation. Albert Einstein published the theoretical basis for the laser in 1917, but it was only in 1960 that the first functioning laser was constructed by Theodore Maiman in California, using a ruby crystal to produce laser light. An extract from the newspaper article following a public demonstration of the laser, read: “Suddenly a light from hell appeared in the middle of the ruby. Then, from the end of a cylinder, a hundred thousand times brighter than the sun, burst forth a thin red light, a perfectly parallel monochromatic beam.[4] Maiman and his assistants were silent for some time, enthralled by the beauty of this spectacle. ‘Einstein was right’ he murmured, ‘light can be concentrated and coherent.”

The device produces a beam of coherent light with a specific wavelength in the infrared, visible or ultraviolet regions of the electromagnetic spectrum. Further development of this technology led to lasers becoming widely used in medical practice.

Components of a laser

A laser consists of 3 basic components

1. A lasing medium or “gain medium”: May be a solid (crystals, glasses), liquid (dyes or organic solvents), gas (helium, CO2) or semiconductors.

2. An energy source or “pump”: May be a high voltage discharge, a chemical reaction, diode, flash lamp or another laser.

3. An optical resonator or “optical cavity”: Consists of a cavity containing the lasing medium, with two parallel mirrors on either side. One mirror is highly reflective and the other mirror is partially reflective, allowing some of the light to leave the cavity to produce the laser’s output beam – this is called the output coupler.[5]

The laser is usually named according to the type of lasing medium. This also determines the type of pump required and the wavelength of the laser light which is produced.

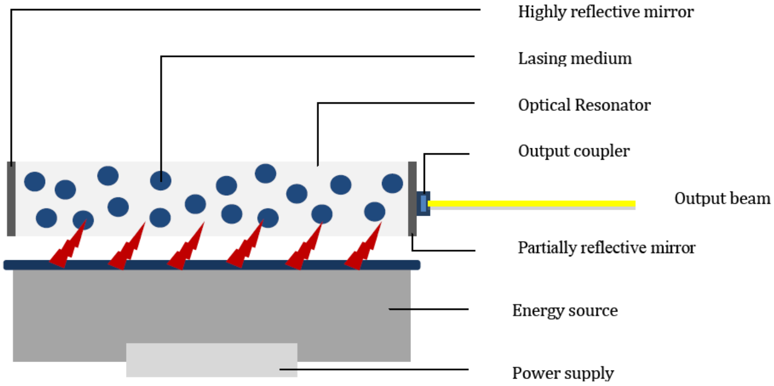

Figure 1. The 3 Components of a laser

Types of laser

There are many types of lasers available for research, medical, industrial, and commercial uses. Lasers are often described by the kind of lasing medium they use - solid state, gas, excimer], dye, or semiconductor.

Solid state lasers have lasing material distributed in a solid matrix, e.g., the ruby or neodymium- YAG (yttrium aluminum garnet) lasers. The neodymium-YAG laser emits infrared light at 1.064 micrometers.

Gas lasers (helium and helium-neon, HeNe, are the most common gas lasers) have a primary output of a visible red light. CO2 lasers emit energy in the far-infrared, 10.6 micrometers, and are used for cutting hard materials.

Excimer lasers (the name is derived from the terms *excited* and *dimers*) use reactive gases such as chlorine and fluorine mixed with inert gases such as argon, krypton, or xenon. When electrically stimulated, a pseudomolecule or dimer is produced and when lased, produces light in the ultraviolet range.

Dye lasers use complex organic dyes like rhodamine 6G in liquid solution or suspension as lasing media. They are tunable over a broad range of wavelengths.

Semiconductor lasers, sometimes called diode lasers, are not solid-state lasers. These electronic devices are generally very small and use low power. They may be built into larger arrays, e.g., the writing source in some laser printers or compact disk players. Low power diode lasers are used for soft tissue treatments. Higher power diode lasers are used in dentistry and medical aesthetics.[6]

Basic principles of lasers

The principle of a laser is based on three separate features: (a) stimulated emission within an amplifying medium, (b) population inversion and (c) an optical resonator.

To explain the process of light amplification in a laser, an understanding of the energy transition phenomena in the atoms of its active medium is required. There are three major aspects of a laser

i) Stimulated absorption: Electrons can be excited from one energy state to another by transferring energy from an external source. So, if a photon (light) comes across an electron in a lower energy state, it can push the electron to a higher energy state. The energy of the photon is now a part of the excited electron. As the electron is stimulated, it absorbs the photons energy. This process is called Stimulated absorption the absorption of a photon by an electron.

ii) Spontaneous emission: After stimulated absorption, we have an excited electron. But the electron will not stay in its excited (upper) state for long, and will “quickly” fall from its excited state to its original state. When we say quickly, we mean roughly 10-8 s (in some cases, although the time varies for different materials). When it falls to its original state, it will release a photon with energy equal to the difference in the energy states. EPhoton ($\hbar\nu$) = E2 - E1, where ħ is the reduced plank constant. The higher the fall, the higher the energy of the emitted photon. If the energy of the photon is in the visible range of wavelength, then we would see it as colour. This process is called Spontaneous emission - the emission of excited energy, i. e. a photon from an electron.

These common processes of absorption and spontaneous emission cannot lead to the amplification of light. The best that can be achieved is that for every photon absorbed, another is emitted.

iii) Stimulated emission: The last process is when a photon interacts with an electron that is already excited. This new photon can force the excited electron to fall back to a lower energy state and emits another photon. We then have two photons: the incoming (stimulated) photon and the emitted photon from the electron. What’s important about this process is that the emitted photon will be identical to the stimulated photon, because the incoming photon has to be of the energy difference between the two states, E2 - E1, and the new emitted photon is by definition the released energy of the electron going from state 2 to state 1, again, E2 - E1. Therefore, the two photons will be identical, and have the same energy, frequency, phase and polarization - they will be coherent with each other.

These processes are shown in Figure 2.

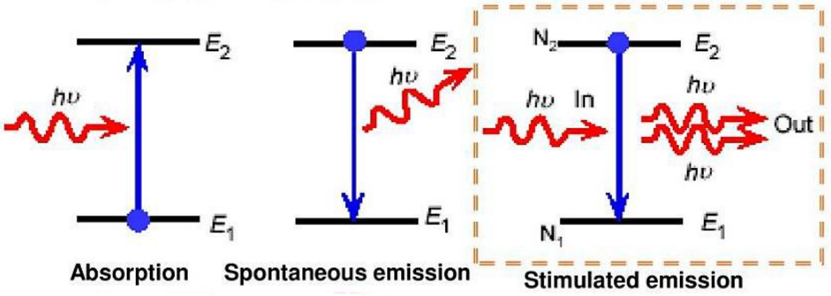

Fig 2: Illustrations for Absorption, Spontaneous and Stimulated Emissions.

All the three processes occur simultaneously within a medium. However, in thermal equilibrium, stimulated emission does not account to a significant extent. The reason is there are far more electrons in the ground state than in the excited states. And the rates of absorption and emission is proportional the number of electrons in ground state and excited states, respectively. So, absorption process dominates.

To obtain a continuous laser beam, metastable state and population inversion are essential.[7]

Laser surgery

Laser surgery is a type of surgery that uses special light beams instead of instruments for surgical procedures. LASER stands for "Light Amplification by the Stimulated Emission of Radiation." Lasers were first developed in 1960.

Newer laser modifications continue to have a large impact on medical and surgical practices. A large part of their impact has been seen in the treatment of various skin lesion and diseases.

Types of surgeries use lasers

There are many indications for the use of lasers in surgery.
The following are some of the more common indications
To remove tumors.
To help prevent blood loss by sealing small blood vessels.
To seal lymph vessels to help decrease swelling and decrease the spread of tumor cells.
To treat some skin conditions, including to remove or improve warts, moles, tattoos, birthmarks, scars, and wrinkles.

The laser and its applications in biomedicine

In 1917, Albert Einstein first theorized about the phenomenon of stimulated emission which is the backbone of the laser. The first working laser, the pulsed ruby laser, was invented by Theodore H. Maiman in 1960. However, there were no potential applications known and in fact it was popularly referred to as a tool looking for applications. Within a few years of the development of the laser its medical application particularly in urology was reported in 1968 by Mulvaney and Beck who used the ruby laser to fragment urinary calculi. They were able to ablate the calculi, but the continuous wave ruby laser generated excessive heat and so its clinical use was not extended. By the mid-1980s the use of the laser to treat stone disease had become established, and the era of laser lithotripsy had begun. Thus the development of potential applications of the laser in medical science has given a new direction to analytical scientists. Over the last few decades the use of lasers had become standard for the treatment and diagnosis of many diseases including the treatment of a range of ophthalmological and dermatological conditions. There are many medical disciplines where lasers are successfully used for a variety of purposes.[8] However, there is a necessity for further research in laser applications in medicine in order to achieve optimal outcomes.

To improve the medical applications of laser based techniques an understanding of the kinetics and dynamics of laser interactions with biological tissues is essential. Knowledge of laser–tissue interactions will guide the identification of optimal laser parameters to achieve more efficient and safer outcomes. The applications of lasers in medicine can be categorized into two major disciplines, namely diagnostic and therapeutic. The vast majority of applications are in the therapeutic field. In recent years, there has also been much interest in the use of the laser as a diagnostic tool and this has resulted in some exciting developments across all medical specialties. Gaining clinical diagnostic information by the use of a laser probe, for example for the analysis of tissue and biomaterials, may better guide treatment and may also be helpful in optimizing the therapeutic technique we will discuss principal applications of lasers in modern medicine. Due to the present boom in developing new laser techniques and due to the limitations given by the dimensions of this book, not all disciplines and procedures can be taken into account. The main intention is thus to focus on the most significant applications and to evoke a basic feeling for using certain techniques. The examples are chosen to emphasize substantial ideas and to assist the reader in grasping some technical solutions. Potential difficulties and complications arising from either method are addressed, as well. However, we should always keep in mind that any kind of laser therapy will not be indicated if alternative methods are available which offer a better rate of success, are less dangerous to the patient, and/or easier to perform. Because of the historic sequence, the first section will be concerned with laser applications in ophthalmology.[9] Even today, the majority of medical lasers sold is applied in this field. Dentistry was the second clinical discipline to which lasers were introduced. However, although considerable research has been done, the results were not quite as promising in most cases, and the discussion on the usefulness of dental lasers still proceeds. Today, the major effort of clinical laser research is focusing on various kinds of tumor treatments such as photodynamic therapy (PDT) and laser-induced interstitial thermotherapy (LITT). These play a significant role in many other medical disciplines like gynecology, urology, and neurosurgery. Due to recent advancements in instrumentation for minimally invasive surgery (MIS), e.g. the development of miniature catheters and endoscopes, novel techniques are under present investigation in angioplasty and cardiology. Very interesting laser applications were found in dermatology and orthopedics. And, recently, successful laser treatments have been reported in gastroenterology, otorhinolaryngology, and pulmology Thus, it can be concluded that – at the present time – laser medicine is a rapidly growing field of both research and application. This is not at all astonishing, since neither the development of novel laser systems nor the design of appropriate application units have yet come to stagnation. Moreover, laser medicine is not restricted to one or a few disciplines.[10] Instead, it has meanwhile been introduced to almost all of them, and it is expected that additional clinical applications will be developed in the near future.

Lasers in Ophthalmology

In ophthalmology, various types of lasers are being applied today for either diagnostic or therapeutic purposes. In diagnostics, lasers are advantageous if conventional incoherent light sources fail. One major diagnostic tool is confocal laser microscopy which allows the detection of early stages of retinal alterations. By this means, retinal detachment and also glaucoma1 can be recognized in time to increase the probability of successful treatment. however, our interest focuses on therapeutic laser applications. The first indications for laser treatment were given by detachments of the retina. Meanwhile, this kind of surgery has turned into a well-established tool and only represents a minor part of today's ophthalmic laser procedures. Others are, for instance, treatment of glaucoma and cataract. And, recently, refractive corneal surgery has become a major field of research, too. The targets of all therapeutic laser treatments of the eye can be classified into front and rear segments. The front segments consist of the cornea, sclera, trabeculum, iris, and lens. The rear segments are given by the vitreous body and retina. A schematic illustration of a human eye is shown in Fig. 3. In the following paragraphs, we will discuss various treatments of these segments according to the historic sequence, i.e. from the rear to the front.

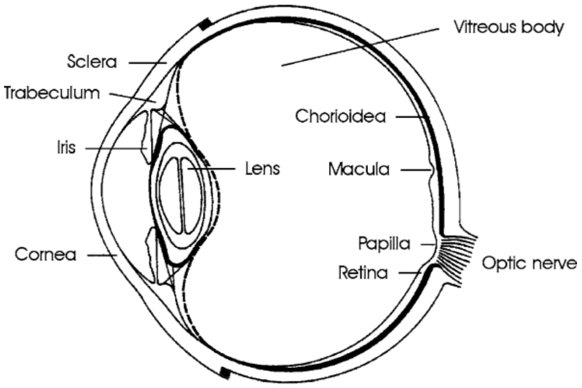

Fig. 3: Since glaucoma is usually associated with a degeneration of the optical nerve fibers, it can be detected by measuring either the thickness of these fibers.[11]

Alterations of the optic disc. Further details are given by Bille et al. (1990).

Retina

The retina is a part of the central nervous system. Its function is to convert an optical image focused on it into nerve impulses of the optic nerve emerging from it. The retina is a thin and rather transparent membrane which is permeated with blood vessels. According to Le Grand and El Hage (1980), the thickness of the retina varies from 0.5mm near the papilla to 0.1mm at the macula2. Anatomically, the retina is subdivided into several different layers, each of them having their own distinct function: pigment epithelium, receptor layer, external limiting membrane, cell layer, nerve fiber layer, and internal limiting membrane. A schematic cross-section of a human retina is shown in Fig. 4.

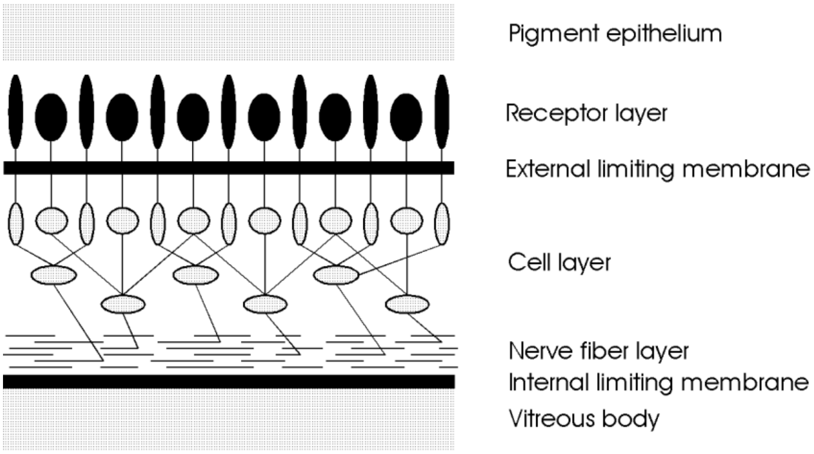

Fig. 4: Cross-section of a human retina.

The pigment epithelium is strongly attached to the chorioidea. The receptor layer consists of two types of cells – rods and cones. Rods are used in dim light and are primarily located around the macula. Cones are recepting colors in good light and are found especially in the fovea. Obviously, light has to pass through virtually the whole retina beyond the external limiting membrane, before it can stimulate any receptor cells. This structural arrangement is known as the "reversed retina" and can be explained by the fact that the retina is an invagination of the embryonic cerebral wall. The cell layer is made up of horizontal cells, bipolar cells, amacrine cells, and ganglion cells. The main function of these cells is to serve as a first network with corresponding receptive fields. Finally, the nerve fiber layer contains the axons of the ganglion cells, whereas the internal limiting membrane forms a boundary between the retina and vitreous body.[12]

The ophthalmologist Meyer-Schwickerath (1949) was the first to investigate the coagulation of the retina with sunlight for therapeutic purposes. Because of the inconvenient circumstances of this kind of surgery, e.g. the necessity of sunshine, he continued his studies with his famous xenon photocoagulator as reported in 1956. Shortly after the invention of the laser by Maiman (1960), first experimental studies with the ruby laser were performed by Zaret et al. (1961). The first reports on the treatment of patients were given by Campbell et al. (1963) and Zweng et al. (1964). They discovered that the ruby laser was a very suitable tool when welding detached segments of the retina to the chorioidea located underneath. However, it also became evident that the ruby laser was not able to close open blood vessels or stop bleeding. It was soon found that the argon ion laser is better suited for this aim. Its green and blue wavelengths are strongly absorbed by the hemoglobin of blood – in contrast to the red light from a ruby laser – which finally leads to the coagulation of blood and blood vessels.[13] At typical exposure durations ranging from 0.1 s to a few seconds, applied laser powers of0.1–1 W, and spot diameters of approximately 200–1000 µm, almost all incident laser energy is converted to heat. Thus, coagulation of retinal tissue is achieved by means of thermal interaction. As discussed in Sect. 3.2, proteins are denatured and enzymes are inactivated, thereby initiating the process of congealment. The surgeon conducts the laser coagulation through a slit lamp and a contact glass. He approaches the necessary laser power from below threshold until the focused area just turns greyish. Coagulation of the macula is strictly forbidden, since it would be associated with a severe loss in vision. The temperatures achieved should generally remain below 80◦C to prevent unnecessary vaporization and carbonization. A good localization of blood vessels, i.e. by confocal laser microscopy, and a precise application of the desired energy dose are mandatory when striving for satisfactory results. At the beginning of the 1970s, the krypton ion laser became very significant for ophthalmic applications. Its red and yellow wavelengths at 647nm and 568 nm, respectively, turned out to be very useful when trying to restrict the interaction zone to either the pigment epithelium or the chorioidea. Detailed histologic studies on this phenomenon were conducted by Marshall and Bird (1979). It was found that the red line is preferably absorbed by the chorioidea, whereas the yellow line is strongly absorbed by the pigment epithelium and also by the xanthophyll contained in the macula. Recently, McHugh et al. (1988) proposed the application of diode lasers, since their invisible emission at a wavelength of approximately 800nm does not dazzle the patient's eye.[14]

There exist six major indications for laser treatment of the retina
– Retinal holes,
– Retinal detachment,
– Diabetic retinopathy,
– Central vein occlusion,
– Senile macula degeneration,
– Retinal tumors (retinoblastoma).

In the case of retinal holes, proper laser treatment prevents their further enlargement which could otherwise lead to retinal detachment. Laser surgery is performed by welding the retina to the underlying chorioidea within a narrow ring-shaped zone around the hole as shown in Fig. 4.3a. The attachment of the coagulated tissue is so strong that further tearing is usually suppressed. If necessary, however, the procedure can be repeated several times without severe complications.

Retinal detachment is often a consequence of undetected retinal holes or tears. It mainly occurs in myopic patients, since the vitreous body then induces an increased tensile stress to the retina. Moderate detachments are treated in a similar mode as retinal holes. In the case of a severe detachment, the treatment aims at saving the fovea or at least a small segment of the macula. This procedure is called panretinal coagulation and is illustrated in Fig. 4.3b. Unfortunately, laser treatment of retinal detachment is often associated with the formation of new membranes in the vitreous body, the retina, or beneath the retina. These complications are summarized by the clinical term proliferative retinopathy.[15] A useful therapeutic technique for the dissection of such membranes was given by Machemer and Laqua (1978).

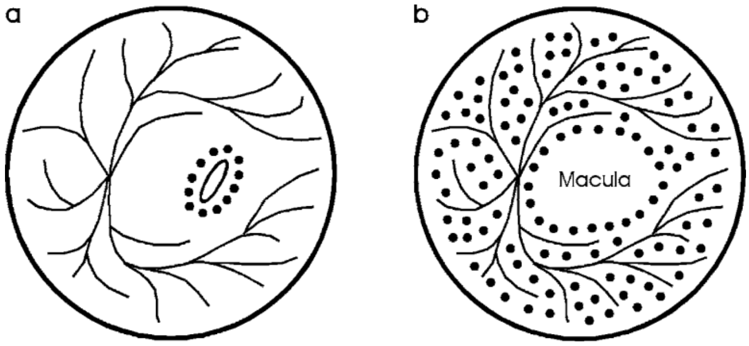

Fig. 4.3: (a) Placement of coagulation spots in the case of retinal holes or moderate detachments. (b) Placement of coagulation spots during panretinal coagulation.

Some Cosmetic Uses of Lasers

Medical lasers are also widely used for various types of cosmetic surgery, including the removal of certain kinds of birthmarks. Port-wine stains, reddish purple skin blotches that appear on about three out of every one thousand children, are an example. Such stains can mark any part of the body but are most commonly found on the face and neck.

Laser surgery in cardiology

Like every other organ or tissue in your body, the heart muscle needs oxygen-rich blood to survive. The heart gets this blood from the coronary arteries. But in patients with coronary artery disease (CAD), the coronary arteries are clogged and diseased and can no longer deliver enough blood to the heart. The heart's lack of oxygen-rich blood is called ischemia. Not getting enough oxygen to the heart muscle increases the risk of heart attack and may cause a painful condition called angina. Most of the time, the best treatment for angina is coronary artery bypass surgery.[16] But for some patients with very serious heart disease or other health problems, bypass surgery may be too dangerous. Also, some patients may have had many coronary artery bypass operations and be unable to have more bypass operations. For patients who cannot have bypass surgery, Fig. 5. there is a procedure called trans myocardial laser revascularization, also called TMLR or TMR. TMLR cannot cure CAD, but it may reduce the pain of angina.

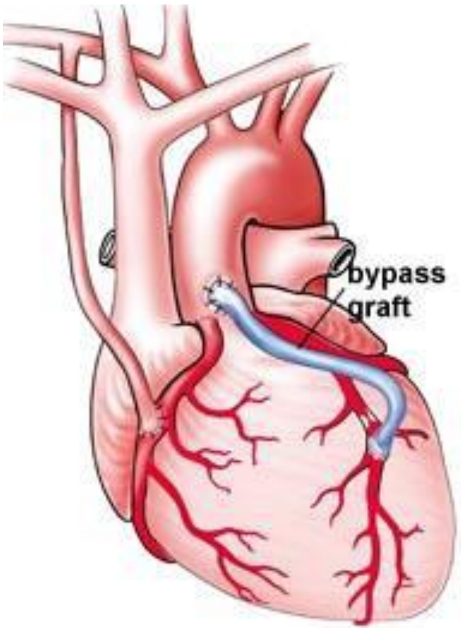

Fig. 5: Laser surgery in neurology.

Lasers generate unidirectional beams of monochromatic, and temporally and spatially coherent electromagnetic radiation that are capable of vaporizing and coagulating biological tissue. Specific physical characteristics of laser energies of different wavelengths impart to each form of surgical laser specific potentials for clinical use in neurological surgery. The major advantages of surgical lasers appear to be improved precision, reduction of surgically related mechanical trauma, reduction of blood loss, and decreased operative time. Improvement of operative mortality and morbidity and increased longevity that might result from its use would make the laser cost effective. Lasers have been used in dentistry since 1994 to treat a number of dental problems. Yet, despite FDA approval, no laser system has received the American Dental Association's (ADA)

Seal of Acceptance as an alternative to more traditional treatment.

Lasers Work in Dentistry

All lasers work by delivering energy in the form of light. When used for surgical and dental procedures, the laser acts as a cutting instrument or a vaporizer of tissue that it comes in contact with. When used in teeth-whitening procedures, Fig. 6. the laser acts as a heat source and enhances the effect of tooth-bleaching agents.

Fig. 6: The Pros and Cons of Using a Laser in Dentistry.

Pros: Compared to the traditional dental drill, lasers

- May cause less pain in some instances, so reduces the need for anesthesia
- May reduce anxiety in patients uncomfortable with the use of the dental drill
- Minimize bleeding and swelling during soft tissue treatments
- May preserve more healthy tooth during cavity removal.[17]

Cons The disadvantages of lasers are that

- Lasers can't be used on teeth with fillings already in place.

Lasers can't be used in many commonly performed dental procedures. For example, lasers can't be used to fill cavities located between teeth, around old fillings, and large cavities that need to be prepared for a crown. In addition, lasers cannot be used to remove defective crowns or silver fillings, or prepare teeth for bridges.

- Traditional drills may still be needed to shape the filling, adjust the bite, and polish the filling even when a laser is used. Fig. 6.

Lasers do not eliminate the need for anesthesia.

Laser treatment tends to be more expensive -- the cost of the laser is much higher than a dental drill. Compared to about $600 for a standard drill, lasers can cost anywhere from a few thousand dollars to over $100,000 for one that can be used for tooth cutting.

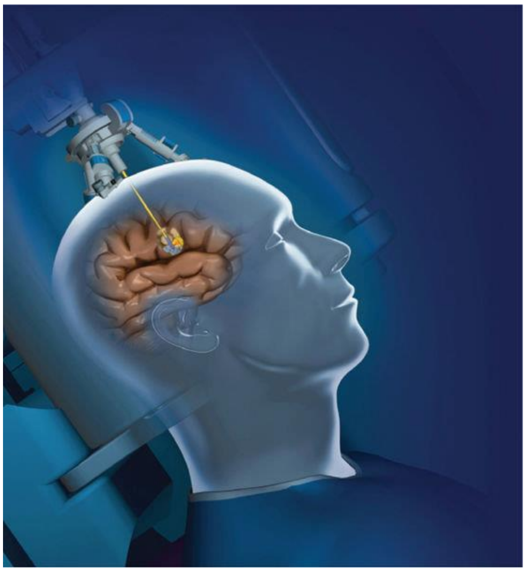

Fig. 6.

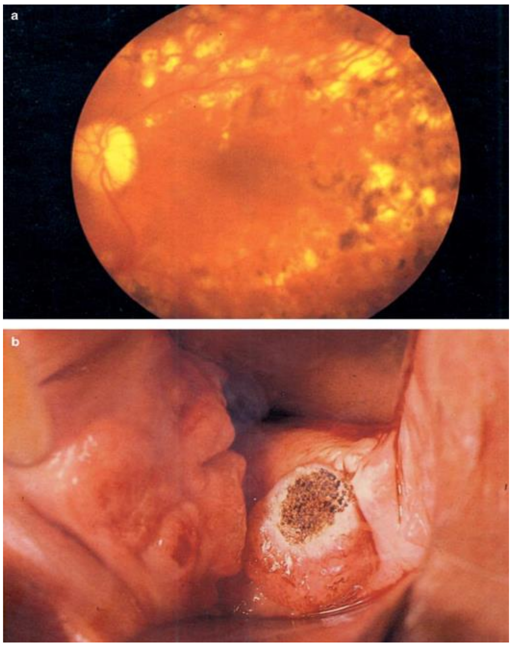

Fig. 7: (a) Panretinal coagulation in a diabetes patient performed with an argon ion laser (power: 200mW). (b) Vaporization of cervical tissue with a CO2 laser (power: 10 W).

Photographs kindly provided by Dr. Burk (Heidelberg) and Dr. Kurek (Heidelberg).

Laser surgery in urology

Lasers obtained from various lasing mediums producing amplified light of different wavelengths have been tested for urological applications. Today, these lasers are most commonly used in the surgical management of benign prostatic hyperplasia and as intracorporeal lithotripters.[18] Other uses include ablation of various urologic tumors and incising strictures of the upper- and lower urinary tract. A continuous process of evolution of this technology is taking place, resulting in surgical lasers becoming ever safer, more effective, and more affordable.

Analysis of stones in different organs of the human body

Lasers have been used to breakdown urinary and kidney calculi since 1987 The laser shock-wave disintegrates the calculus into tiny fragments. Fang et al. used LIBS for the quantification of the elemental contents Ca, Mg, Na, Sr, K and Pb in urinary calculi, and they concluded that LIBS offers the possibility to accurately measure trace elements in such stones without the need for any elaborate sample preparation. Recently, Singh et al. . characterized qualitatively and quantitatively the different types of gallbladder stone (cholesterol stones, pigment stones, mixed stones). They analysed different parts of the gallstones and found higher levels of metal elements in the centre than in the shell and surface of the gallstones. Singh et al. also reported the use of LIBS for the in situ quantitative estimation of the elemental constituents in different parts of kidney stones (centre, shell and surface parts) obtained during surgery. They estimated the quantities of Cu, Zn, Mg and Sr in the stones using calibration curves. They also used the ratios of the intensities of the different elemental lines to determine the spatial distribution of different elements inside.[18]

Analysis of minerals in the human body

Discussed the utility of the LIBS technique for the analysis of minerals and potentially toxic elements present in calcified tissues including bones and teeth to study the influence of environmental exposure and other biomedical factors. They investigated the multidimensional profiles of the elements present in the teeth and bone samples. Recently, the use of LIBS for the rapid identification of teeth affected by caries has been demonstrated by Singh and Rai.

They were able to detect a broad range of elements including Ca, Mg, Cu, Zn, Sr, Ti, C, P, H, O, Na and K. They found that the caries-affected part of the teeth contained lower amounts of Ca and P than the healthy part, but higher amounts of Mg, Cu, Zn, Sr, C, Na, K, H and O. They explained the presence of the different metal elements present in the teeth and also discussed their role in the formation of caries.

Laser treatment of water: a method used in various scientific and industrial applications, can produce notable physical and chemical changes. When a laser beam interacts with water, its effects depend on the laser's wavelength, intensity.

One primary effect is photothermal. Here, laser energy converts into heat, causing localized temperature increases. This heating can lead to the evaporation of water molecules,creating microbubbles. The formation and collapse of these bubbles generate shock waves, which can enhance cleaning and sterilization processes by disrupting contaminants and microbial cells.

Another significant effect is photochemical. Lasers can induce chemical reactions in water, leading to the formation of reactive species such as hydroxyl radicals. These radicals are highly reactive and can break down organic pollutants, making laser treatment an effective method for degrading harmful compounds in wastewater. This process, known as advanced oxidation, is a potent tool for purifying water by breaking down complex organic molecules into simpler, less harmful substances.

Furthermore, laser irradiation can also cause structural changes in water. For instance, high-intensity lasers can alter the hydrogen bonding network within water, impacting its properties and potentially enhancing its solubility and reactivity. In summary, the application of lasers to water can lead to significant photothermal, photochemical, and structural changes. These effects are harnessed in various fields to clean, sterilize, and modify water, making laser treatment a versatile and powerful tool in both industrial and environmental contexts.

Lasers interact with air through various mechanisms depending on their wavelength, power, and the properties of the air. Key effects include scattering, absorption, and ionization.

Scattering occurs when the laser light is redirected by particles and molecules in the air. This can be either elastic (Rayleigh scattering) for molecules smaller than the wavelength, or inelastic (Raman scattering), which involves a change in energy and wavelength. Rayleigh scattering causes lasers to lose intensity and is more pronounced for shorter wavelengths, making blue and ultraviolet lasers more affected.

Absorption happens when laser photons are absorbed by molecules in the air, raising their energy levels. Different gases absorb specific wavelengths; for example, water vapor absorbs infrared light effectively. This absorption can heat the air, leading to thermal effects like the creation of shock waves or changes in air density. High-power lasers can cause significant heating and even create plasma if the energy is high enough.[19]

Ionization involves removing electrons from air molecules, creating ions and free electrons. This occurs at very high laser intensities, typically with ultra-short pulses. The ionization process can lead to the formation of plasma, a state of matter where electrons and ions coexist. This plasma can absorb and reflect laser light, further interacting with the laser beam.

Lasers can also induce nonlinear effects in air: Such as self-focusing and filamentation, where the beam maintains a narrow path over long distances. These effects arise from the interplay between the laser's electric field and the air's refractive index.

In summary, the interaction of lasers with air involves complex processes that depend on the laser's characteristics and the air's composition. These interactions have practical implications for laser communication, atmospheric sensing, and laser-induced plasma generation.

The effects of lasers on foods can be broadly categorized into processing, quality enhancement, and safety. Here’s a detailed look at these aspects.

Processing

Laser Cutting and Engraving

Laser cutting is a precise method that uses focused light beams to slice through food materials. This technique is particularly useful for delicate foods that might be damaged by traditional mechanical methods. For instance, lasers can be used to cut intricate shapes in confectionery items or to precisely portion meat and vegetables. The advantages of laser cutting include minimal waste, high accuracy, and the ability to create detailed designs without physical contact, reducing the risk of contamination.

Laser Drilling

This technique involves using lasers to create holes in food items, which can be useful in processes like controlled dehydration or infusion of flavors. For example, laser drilling can be used to create micro-perforations in fruits to allow for quicker drying in the production of dried fruits, or to inject marinades into meat products more efficiently.

Quality Enhancement

Laser Marking

Lasers can also be used for marking foods. This includes etching information such as expiry dates, batch numbers, or logos directly onto the food surface. Unlike ink-based marking, laser marking does not involve any additional substances, which ensures the markings are food-safe and tamper-proof. Additionally, laser marking can be used for traceability, which is essential for quality control and food safety management.

Texture Modification

Lasers can be used to modify the texture of certain food products. For example, in the baking industry, lasers can be employed to create surface textures on dough products, which can influence the final baked product’s appearance and mouthfeel. By controlling the laser parameters, manufacturers can achieve desired textural properties that enhance the consumer’s sensory experience.

Safety

Microbial Inactivation

One of the significant applications of lasers in food safety is microbial inactivation. Laser light, particularly at certain wavelengths (like ultraviolet), has germicidal properties. This can be used to sterilize surfaces of food products, packaging materials, and equipment. The non-thermal nature of this process means that it does not alter the sensory and nutritional qualities of the food, unlike traditional heat treatments.

Pesticide Residue Degradation

Lasers can also play a role in breaking down pesticide residues on the surface of fruits and vegetables. This is done by using laser-induced photolysis, which involves breaking down chemical compounds using laser light. This process can help in reducing the levels of harmful residues, making the food safer for consumption.

Research and Future Directions

Non-destructive Testing

Lasers are being explored for their potential in non-destructive testing (NDT) of foods. Techniques like laser-induced breakdown spectroscopy (LIBS) and laser-induced fluorescence (LIF) can be used to analyze the composition and detect contaminants in food products without damaging them. These methods provide rapid and reliable results, which are crucial for maintaining food quality and safety.

Innovative Preservation Methods

Researchers are investigating the use of lasers for innovative food preservation techniques. For example, laser-based methods are being explored to create protective barriers on food surfaces, which can extend shelf life and reduce spoilage.[21] These methods involve altering the surface properties of food to make them less susceptible to microbial growth and oxidation.

In conclusion, the application of lasers in the food industry offers numerous benefits in terms of processing efficiency, quality enhancement, and safety. As technology advances, the scope of laser applications in food science is expected to expand, leading to even more innovative and sustainable practices in food production and preservation

Negative Environmental Impacts

Resource Extraction The production of lasers involves the extraction of rare earth elements and other materials, which can have significant environmental impacts. Mining for these elements often leads to habitat destruction, soil erosion, water contamination, and air pollution. Moreover, the refining and processing of these materials are energy-intensive and generate hazardous waste, further exacerbating environmental problems. E-Waste As with other electronic devices, lasers contribute to the growing problem of electronic waste (e-waste). Discarded laser equipment, including medical devices, industrial machines, and consumer electronics, often contains hazardous materials that can leach into the soil and water, posing risks to human health and the environment. Proper disposal and recycling of laser equipment are essential to mitigate these risks, but e-waste management remains a significant global challenge.[20] Thermal Pollution High-powered lasers used in industrial and military applications can generate substantial amounts of heat. This thermal pollution can affect local ecosystems, particularly in aquatic environments. For example, lasers used in industrial processes may heat nearby water sources, disrupting the habitat of aquatic organisms and potentially leading to thermal shock, which can be fatal to sensitive species. Mitigation Strategies To minimize the negative environmental impacts of laser technology, several strategies can be employed: Sustainable Manufacturing Adopting sustainable manufacturing practices can reduce the environmental footprint of laser production. This includes using renewable energy sources, recycling materials, and implementing energy-efficient processes. Manufacturers can also invest in research and development to create lasers that require fewer rare earth elements or other environmentally damaging materials. Energy Management Improving energy management in laser applications is crucial. This can be achieved by optimizing laser systems for energy efficiency, using energy-saving modes, and integrating renewable energy sources.[22] Additionally, advancements in laser technology, such as the development of more efficient diode lasers, can help reduce energy consumption. Recycling and E-Waste Management Proper disposal and recycling of laser equipment are essential to mitigate the environmental impact of e-waste. Establishing robust e-waste management systems, promoting the recycling of laser components, and encouraging the design of lasers for easy disassembly and recycling can help address this issue. Governments and industries should work together to implement regulations and standards for the safe disposal and recycling of laser equipment.[23] Environmental Monitoring Using lasers for environmental monitoring and pollution control can help mitigate their own environmental impact. Laser-based sensors and monitoring systems can provide real-time data on pollution levels, enabling more effective environmental management and regulatory enforcement. This proactive approach can help identify and address pollution sources before they cause significant harm to the environment.[24] Conclusion Laser technology offers numerous benefits, including energy efficiency, waste reduction, and pollution control. However, it also poses environmental risks, such as energy consumption, resource extraction, e-waste, and thermal pollution. By adopting sustainable manufacturing practices, improving energy management, promoting recycling and e-waste management, and utilizing lasers for environmental monitoring, we can mitigate these risks and harness the positive potential of laser technology.[25] As the demand for laser applications continues to grow, it is essential to balance technological advancement with environmental stewardship to ensure a sustainable future.

Summary and future prospects

In this review we present the most recent developments in LIBS in the field of biomedicine. In the past decade there has been a burst of research activity in the use of LIBS for the analysis of trace elements in biomedicine matrices. As noted at the beginning of this review, LIBS is an effective technology with a wide range of potential applications in the detection and monitoring of major and trace elements in the human body, and LIBS technology has great potential for clinical practice.[26] Many of these applications cannot be addressed using conventional analytical methods such as AAS, ICP, and XRF, but can be solved using LIBS. For the quantitative analysis of biomaterials where CRMs are available to prepare a calibration curve, the utility of CF-LIBS for determining the concentrations of the major and minor elements present in biological samples has been proven. Improving instrumentation, understanding the laser plasma, and data analysis are currently active areas of LIBS research.[27]

REFERENCES

1. W. T. Silfvast, Laser Fundamentals, Cambridge University Press, New Delhi, India, 2004.
2. Handbook of Laser Technology and Applications, edited by Webb C E & Julian D C Jones, Institute of Physics Publishing (IOP), Dirac House, Temple back, Bristol BSI 6BE, UK, 2004.
3. Einstein, *Verhandlungen der Deutschen Physikalischen Gesellschaft*, 1916; 18: 318.
4. Einstein, Zur quantentheorie der strahlung. *Physikalische Zeitschrift*, 1917; 18: 121.
5. T. H. Maiman, Stimulated Optical Radiation in Ruby, *Nature*, 1960; 187: 493.
6. K. Thyagarajan and A. K. Ghatak, Lasers: Theory and Applications, Macmillan India Ltd. New Delhi, India, 2004.
7. M. M. Adadhanulu and P. S. Hemne, an Introduction to Lasers: Theory and Applications, S. Chand & Company, New Delhi, India, 2012.
8. J. Hecht, Understanding Lasers, 4th ed., Wiley-IEEE Press, 2018.
9. O. Svelto, Principles of Lasers, Plenum: New York, 1998.
10. Qian Peng, Asta Juzeniene, Jiyao Chen, Lars O Svaasand, Trond Warloe, Karl-Erik Giercksky and Johan Moan, Lasers in Medicine, *Rep. Prog. Phys.*, 2008; 71: 056701.
11. D. R. Vij and K. Mahesh, *Medical Applications of Lasers*, Springer Verlag, 2014.
12. D. H. Sliney and S. L. Trokel, *Medical lasers and their safe use*, New York: Springer-Verlag, 2012.
13. M. M. Jawad, S. T. Abdul Qader, A.A. Zaidan, B.B. Zaidan, A.W. Naji and Ibraheem T. Abdul Qader, An Overview of Laser Principle, Laser-Tissue Interaction Mechanisms and Laser Safety Precautions for Medical Laser Users, *International Journal of Pharmacology*, 2011; 7: *149.*
14. K R. Nambiar, “Laser Principle’s Types and Applications”, New age international P limited publishers, 2004.
15. Kaya Ball, “Lasers the Perioperative Challenge”, second Edition, Published in Nabcy L. Coon, USA, 1995.
16. Saravana Kumar, A., Hameed Hussain, J., Expanding the pass percentage in semester examination, International Journal of Pure and Applied Mathematics, Special Issue, 2017; 116(15): 45-48.
17. Saravana, S., Arulselvi, S., AdaBoost SVM based brain tumour image segmentation and classification, International Journal of Pure and Applied Mathematics, Special Issue, 2017; 116(20): 399-403.
18. Saravana, S., Arulselvi, S., Dynamic power management monitoring and controlling system using wireless sensor network, International Journal of Pure and Applied Mathematics, Special Issue, 2017; 116(20): 405-408.
19. Saravana, S., Arulselvi, S., Clustered morphic algorithm based medical image analysis, International Journal of Pure and Applied Mathematics, Special Issue, 2017; 116(20): 411-415.
20. Saravana, S., Arulselvi, S., Networks, International Journal of Pure and Applied Mathematics, Special Issue, 2017; 116(20): 393-396.
21. Saritha, B., Chockalingam, M.P., Adsorptive removal of heavy metal chromium from aqueous medium using modified natural adsorbent, International Journal of Civil Engineering and Technology, 2017; 8(8): 1382-1387.
22. Saritha, B., Chockalingam, M.P., Adsorptive removal of brilliant green dye by modified coconut shell adsorbent, International Journal of Pure and Applied Mathematics, Special Issue, 2017; 116(13): 211-215.
23. Saritha, B., Chockalingam, M.P., Photodegradation of eriochrome black-T dye from aqueous medium by photocatalysis, International Journal of Pure and Applied Mathematics, Special Issue, 2017; 116(13): 183-187.
24. Saritha, B., Chockalingam, M.P., Photodradation of malachite green DYE using TIO<inf>2</inf>/activated carbon composite, International Journal of Civil Engineering and Technology, 2017; 8(8): 156-163.
25. Saritha, B., Chockalingam, M.P., Synthesis of photocatalytic composite Fe-C/TiO2 for degradation of malachite green dye from aqueous medium, International Journal of Pure and Applied Mathematics, Special Issue, 2017; 116(13): 177-181.
26. Saritha, B., Chockalingam, M.P., Removal of heavy X`X`l from aqueous medium using modified natural adsorbent, International Journal of Pure and Applied Mathematics, Special Issue, 2017; 116(13): 205-210.
27. Saritha, B., Chockalingam, M.P., Degradation of malachite green dye using a semiconductor composite, International Journal of Pure and Applied Mathematics, Special Issue, 2017; 116(13): 195-199. Teeth. Lasers Med Sci., 26: 307–315.