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Review Article about Laser and its Applications

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Annotation: Laser technology has revolutionized various fields, from medicine to industry, due to its precision, coherence, and high energy efficiency. Despite extensive research, challenges remain in optimizing laser applications for medical treatments, industrial manufacturing, and scientific advancements. This review explores different types of lasers, their working principles, and their diverse applications, including spectroscopy, optical tweezers, surgery, and telecommunications. Through an analysis of recent developments, findings indicate that laser-based technologies continue to enhance efficiency, accuracy, and safety across multiple disciplines. The results emphasize the growing significance of laser innovations in modern technology, highlighting the need for further research into advanced laser systems for improved performance and broader applications.

Keywords: Laser technology, laser applications, spectroscopy, medical lasers, industrial lasers, optical tweezers.

Introduction

A laser is a device that emits light through a process of optical amplification based on the stimulated emission of electromagnetic radiation or LASER is light amplification by stimulated emission of radiation and Lasers are classified into 4 types based on the type of laser medium used Solid-state laser, Gas laser, Liquid laser, Semiconductor laser [1].

We propose that the threshold of a laser is more appropriately described by the pump power (or current) needed to bring the mean cavity photon number to unity, rather than the conventional ‘‘definition’’ that it is the pump power at which the optical gain equals the cavity loss. In general the two definitions agree to within a factor of 2, but in a class of micro cavity lasers with high spontaneous emission coupling efficiency and high absorption loss, the definitions may differ by several orders of magnitude. We show that in this regime the laser undergoes a transition from a linear (amplifier) behavior to a nonlinear (oscillatory) behavior at our proposed threshold pump rate. The photon recycling resulting from the high spontaneous emission coupling efficiency and high absorption may in this case result in lasing without population inversion, and coherent light is generated via ‘‘loss saturation’’ instead of gain saturation. This mechanism for lasing without inversion is very different from lasing without inversion using a radiation trapped [2].

The diversity of the chapters presented in this volume illustrates not only the many applications of lasers, but also the fact that, in many cases, these are not new uses of lasers, but rather improvements of laser techniques already widely accepted in both research and clinical situations. Biological reactions to some special aspects of laser exposure continue to show new effects, which have implications for the ever-present topic of laser safety. Such biological reactions are included in fields of research which depend on properties of electromagnetic radiation exposure only possible with lasers, for example, the short pulses necessary for the temperature-jump experiments reviewed by

Reiss: Specialty lasers, such as the transverse excitation atmospheric (TEA) or excimer lasers, add new wavelengths and pulse domains to those already [2].

Available for biological application. A description of these new types of lasers by Osgood is included to indicate new possibilities for future use and to avoid limiting our coverage to well-developed present-day applications. Hillenkamp and Kaufmann describe a microprobe mass spectrograph for analysis of the minute amounts of material evaporated by a laser pulse. The analytical possibilities of this instrument are far-reaching, and some of the various results are described to illustrate the power of their method, as well as to show the types of problems that are suitable for it. The initial steps in photosynthesis have become the subject of intensive investigation [3].

Laser technology has been qualified for micro technology because of its high lateral resolution by minimized focus ability down to a few microns, low heat input and high flexibility. Some examples for laser applications are micro welding, soldering, selective bonding of silicon and glass, micro structuring and laser assisted forming [4].

Use of lasers has revolutionized the study and applications of radiation pressure. Light forces have been achieved which strongly affect the dynamics of individual small particles. It is now possible to optically accelerate, slow, stably trap, and manipulate micrometer-sized dielectric particles and atoms. This leads to a diversity of new scientific and practical applications in fields where small particles play a role, such as light scattering, cloud physics, aerosol science, atomic physics, quantum optics, and high-resolution spectroscopy [5].

Literature survey

In (2000) **T. Töpfer and J. Hein et al. ,** [6] studied In this paper we

various fluoride-phosphate laser glasses relative to fused silica using degenerate four-wave mixing. We find good agreement with empirical estimates obtained from the d-line linear refractive index and the Abbe number

adding sulfate and niobium oxide to the glass composition offering tailorable

nonlinear properties for glasses employed in short pulse laser oscillators.

In (2001) **Ronald W. Waynant and Ilko K. Ilev et al.,** [7] studied the mid–infrared (mid–IR) should be a fruitful area for medical research and instrumentation since this is the region where the most identifiable molecular molecules absorb and radiate. Due to the unique specificity of a biological molecule's spectrum in the mid–IR, semiconductor lasers in the mid–IR have a unique advantage over ultraviolet and visible or near–IR lasers. Small room– temperature laser diodes can be used in small hand–held, portable, and hopefully inexpensive, medical devices for rapid measurement, possibly in patient–operated home–care devices.

In (2002) **Osche and Gregory R.,** [8] studied A comprehensive treatment of the fundamentals of optical detection theory Laser system applications are becoming more numerous, particularly in the fields of communications and remote sensing. Filling a significant gap in the literature, Optical Detection Theory for Laser Applications addresses the theoretical aspects of optical detection and associated phenomenologist, describing the fundamental optical, statistical, and mathematical principles of the modern laser system. The book is especially valuable for its extensive treatment of direct detection statistics, which has no analog in radar detection theory and which has never before been compiled in a cohesive manner in a single book. Coverage includes

In (2003) **LJ Walsh**, [9] studied A range of lasers is now available for use in dentistry. This paper summarizes key current and emerging applications for lasers in clinical practice. A major diagnostic application of low power lasers is the detection of caries, using fluorescence elicited from hydroxyapatite or from bacterial by-products. Laser fluorescence is an effective method for detecting and quantifying incipient occlusal and cervical carious lesions, and with further refinement could be used in the same manner for proximal lesions.

In (2004) **Carmen D. M. Todea,** [10] studied the emergence of laser system occupies a special place in the history of scientific innovations, the first operational laser systems being developed early in the 60’s. Laser was proposed as a mechanism by the American physicians Hard Townes and Arthur L. Schawlow, in 1953. Their achievement was a “Maser Optic”, a device that, for the first time, could emit visible light, and not microwaves. Based on this idea, the first laser was completed, the consequent development being based on the use of knowledge from the field of microwaves (in 1960, the physicist

In (2005) **Arnold Gillner and JensHoltkamp et al.,** [11] studied The production and machining of micro parts were in the past mainly made by technologies developed from the electronic industry, which is particularly based on silicon etching technologies for the production of, e.g., sensor elements. Due to the increasing demand for micro products in other production area such as medical-, automotive-, optical- and chemical-industry, suitable processes for machining parts from non-silicon materials has become increasingly more important.

In (2006) **BADER, Carl, KREJCI and Ivo,** [12] studied since the early 1960s, lasers have been used in medicine and dentistry. Research and studies have prepared the pathway for cavity preparation without pain and discomfort. Different wavelengths have been tested with variable results and several lasers have shown serious side-effects which could cause damage to dentin and enamel while insufficiently cutting dental hard tissues.1 Stimulated emission from Er^{3+} ions in crystals of yttrium, aluminum and garnet was presented in 1975, preparing the pathway to a new type of laser called Er:YAG.

In (2007) **Herbert Deppe and Hans-Henning Horch**, [13] studied Lasers have been used for many years in oral surgery and implant dentistry. In some indications, laser treatment has become state of the art as compared to conventional techniques. This article is a comprehensive review of new laser applications in oral surgery and implant dentistry. One of the most interesting

It has been shown in the recent literature that the use of this new device can preserve tissue with almost no adverse effects at the light microscopic level

In (2008) **F Perales and F Agulló-Rueda et al.,** [14] Studied Multilayers of MgF_2 and Sb_2S_3 have been obtained by physical vapor deposition on glass substrates. Changes in the optical and structural properties have been studied as a function of annealing temperature and the number of layers. A drastic variation in optical transmission, microstrain and grain size is observed at a temperature near 225 °C. A comparison of the material properties of multilayers and a monolayer is carried out.

In (2009) **Zahed Mohammedi**, [15] studied the search for new devices and technologies for endodontic procedures always has been challenging. Since the development of the ruby laser by Maiman in 1960 and the application of the laser for endodontics by Weichman in 1971, a variety of potential applications for lasers in endodontics have been proposed. With the development of thinner, more flexible and durable laser fibres, laser applications in endodontics have increased. Since laser devices are still relatively costly, access to them is limited. The purpose of this paper is to summarise laser applications in endodontics, including their use in pulp diagnosis, dentinal hypersensitivity, pulp capping and pulpotomy, sterilization of root canals, root canal shaping and obturation and apicectomy. The effects of lasers on root canal walls and periodontal tissues are also reviewed.

In (2010) **R. Bartlome and B. Strahm,** [16] studied we review laser applications in thin-film photovoltaics (thin-film Si, CdTe, and Cu (In, Ga) Se2 solar cells). Lasers are applied in this growing field to manufacture modules, to monitor Si deposition processes, and to characterize opto-electrical properties of thin films. Unlike traditional panels based on crystalline silicon wafers, the individual cells of a thin-film photovoltaic module can be serially interconnected by laser scribing during fabrication. Laser scribing applications are described in detail, while other laser-based fabrication processes, such as laser-induced crystallization and pulsed laser deposition, are briefly reviewed

In (2011**) L. C. Martens,** [17] studied the aim of this introduction to this special laser issue is to describe some basic laser physics and to delineate the potential of laser-assisted dentistry in children. REVIEW: A brief review of the available laser literature was performed within the scope of paediatric dentistry. Attention was paid to soft tissue surgery, caries prevention and diagnosis, cavity preparation, comfort of the patient, effect on bacteria, long term pulpal vitality, endodontics in primary teeth, dental traumatology and low level laser therapy

In (2012) **Xiaogang Liu and Jacqueline M. Cole et al.,** [18] Studied Coumarin derivatives are used in a wide range of applications, such as dye- sensitized solar cells (DSCs) and dye lasers, and have therefore attracted considerable research interest. In order to understand the molecular origins of their optoelectronic properties, molecular structures for 29 coumarin laser dyes are statistically analyzed. To this end, data for 25 compounds were taken from the Cambridge Structural Database and compared with data for four new crystal structures of coumarin laser dyes [Coumarin 487 ($C_{19}H_{23}NO_2$), Coumarin 498 ($C_{16}H_{17}NO_4S$), Coumarin 510 ($C_{20}H_{18}N_2O_2$), and Coumarin 525 ($C_{22}H_{18}N_2O_3$)], which are reported herein.

In (2013) **G N Makarov,** [19] studied The fact that nanoparticles and nanomaterials have fundamental properties different both from their constituent atoms or molecules and from their bulk counterparts has stimulated great interest, both theoretical and practical, in nanoparticles and nanoparticle- based assemblies (functional materials), with the result that these structures have become the subject of explosive research over the last twenty years or so. A great deal of progress in this field has relied on the use of lasers.

In (2014) **Hong-Hua Fang and Jie Yang et al.,** [20] studied Because of long-range order and high chemical purity, organic crystals have exhibit unique properties and attracted a lot of interest for application in solid-state lasers. As optical gain materials, they exhibit high stimulated emission cross section and broad tunable wavelength emission as similar to their amorphous counterpart; moreover, high purity and high order give them superior properties such as low scattering trap densities, high thermal stability, as well as highly polarized emission.

In (2015) **N. von den Driesch and D. Stange,** [21] studied The recent observation of a fundamental direct bandgap for GeSn group IV alloys and the demonstration of low temperature lasing provide new perspectives on the fabrication of Si photonic circuits. This work addresses the progress in GeSn alloy epitaxy aiming at room temperature GeSn lasing. Chemical vapor deposition of direct bandgap GeSn alloys with a high Γ- to L-valley energy separation and large thicknesses for efficient optical mode confinement is presented and discussed.

Aim of work

- ✓ The aim of the research study is to clarify the best type of laser.
- ✓ Studying each type of laser.
- ✓ Study of the most important applications of laser.
- ✓ Study of the types of optical resonator.
- ✓ Study the parts of the laser.

Energy level

A laser is not itself a source of energy; rather, it needs energy from an external source in order to continually maintain population inversion. An external source of energy, called the pump source, excites the atoms in the active medium to the metastable state. Although a variety of techniques have been used in laser pumping, the most common methods are optical pumping and electrical pumping, Three-level lasers are not an optimal solution for laser operation; a more efficient method involves four energy levels. A four-level laser adds an additional energy level above the ground state, which becomes the lower level for the laser emission transition [24].

PROPERTIES OF LASER LIGHT

1. Monochromatic: Because the photons emitted by a laser all correspond

To the same energy transition, they all have the same frequency. Single frequency light such as this is often described as monochromatic.Laser light is not perfectly monochromatic there is some “spread” due to Doppler shifts from the motion of atoms or molecules within the active medium [25].

2. Directional: The light from a laser emerges as a very narrow beam with very little divergence, or spread. We often refer to a beam with this property as being collimated. If you’ve used a laser pointer while giving a presentation or distracting a feline companion, you are familiar with the ability of lasers to project a point of light, even from a relatively large distance. A laser’s high degree of collimation is a direct result of the precise alignment of the parallel mirrors that form the optical cavity [25].
3. Coherent: Light that is made up of waves that are “in-phase” relative to one another is said to be coherent. In other words, the peaks and troughs of the waves exactly align. Coherence in laser light is important for observing interference effects, which has important applications in precision measurement. Interferometry is the use of superimposed waves to make extremely fine measurements of small displacements, surface irregularities, or changes in refractive index [26].

Types of lasers

Lasers are classified into 4 types based on the type of laser medium used:

Solid-state laser

Gas laser

Liquid laser

Semiconductor laser

Solid-state laser

A solid-state laser is a laser that uses solid as a laser medium. In these lasers, glass or crystalline materials are used.

Ions are introduced as impurities into host material which can be a glass or crystalline. The process of adding impurities to the substance is called doping. Rare earth elements such as cerium (Ce), erbium (Eu), terbium (Tb) etc are most commonly used as dopants [27].

Materials such as sapphire (Al2O3), neodymium-doped yttrium aluminum garnet (Nd:YAG), Neodymium-doped glass (Nd:glass) and ytterbium-doped glass are used as host materials for laser medium. Out of these, neodymium-doped yttrium aluminum garnet (Nd:YAG) is most commonly used. The first solid-state laser was a ruby laser. It is still used in some applications. In this laser, a ruby crystal is used as a laser medium [27].

In solid-state lasers, light energy is used as pumping source. Light sources such as flashtube, flash lamps, arc lamps, or laser diodes are used to achieve pumping, as figure (2.1). Semiconductor lasers do not belong to this category because these lasers are usually electrically pumped and involve different physical processes [28].

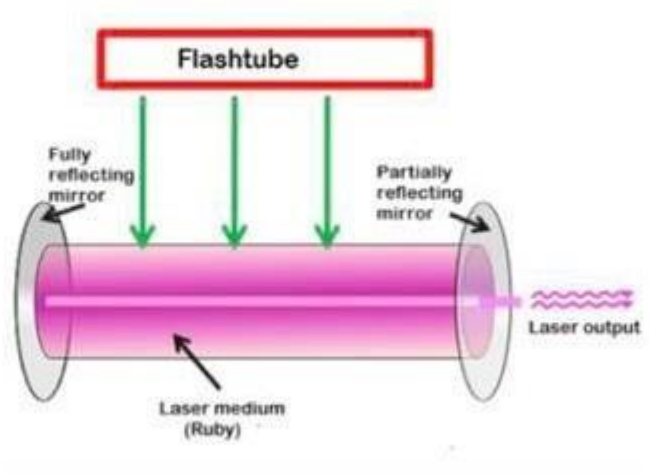

Figure (2.1): Solid- state laser [28].

Gas laser

A gas laser is a laser in which an electric current is discharged through a gas inside the laser medium to produce laser light. In gas lasers, the laser medium is in the gaseous state, Gas lasers are used in applications that require laser light with very high beam quality and long coherence lengths, In gas laser, the laser medium or gain medium is made up of the mixture of gases. This mixture is packed up into a glass tube, as figure (2.2). The glass tube filled with the mixture of gases acts as an active medium or laser medium [29].

A gas laser is the first laser that works on the principle of converting electrical energy into light energy. It produces a laser light beam in the infrared region of the spectrum at 1.15 µm, Gas lasers are of different types: they are, Helium (He) – Neon (Ne) lasers, argon ion lasers, carbon dioxide lasers (CO2 lasers), carbon monoxide lasers (CO lasers), excimer lasers, nitrogen lasers, hydrogen lasers, etc. The type of gas used to construct the laser medium can determine the lasers wavelength or efficiency [30].

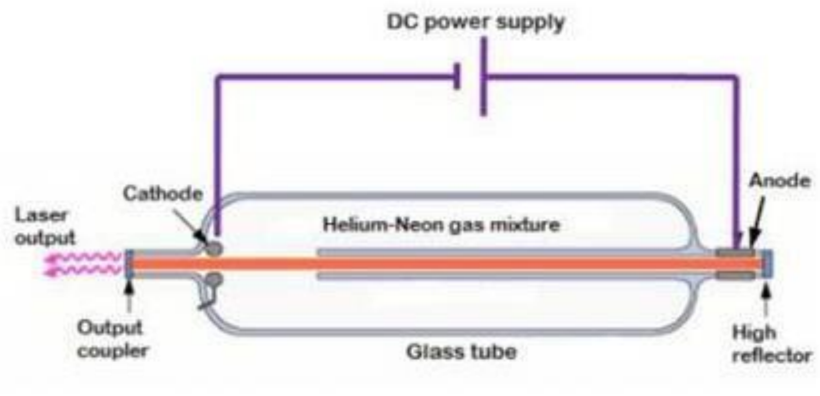

Figure (2.2): Gas laser [29].

Liquid laser

A liquid laser is a laser that uses the liquid as laser medium. In liquid lasers, light supplies energy to the laser medium, a dye laser is an example of the liquid laser. A dye laser is a laser that uses an organic dye (liquid solution) as the laser medium, a dye laser is made up of an organic dye mixed with a solvent. These lasers generate laser light from the excited energy states of organic dyes dissolved in liquid solvents, as figure (2.3). It produces laser light beam in the near ultraviolet (UV) to the near infrared (IR) region of the spectrum [31].

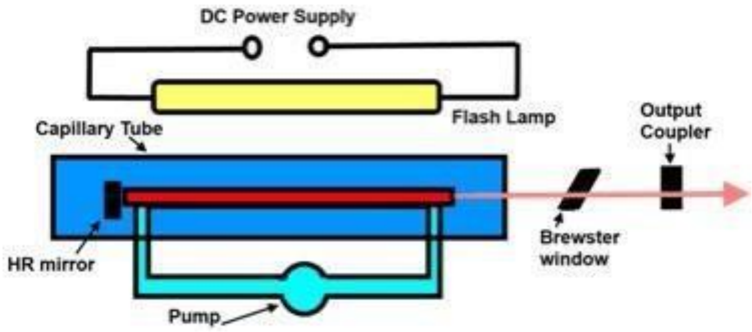

Figure (2.3): Liquid laser [31].

2.2.4 Semiconductor laser

Semiconductor lasers play an important role in our everyday life. These lasers are very cheap, compact size and consume low power. Semiconductor lasers are also known as laser diodes, as figure (2.4). Semiconductor lasers are different from solid-state lasers. In solid-state lasers, light energy is used as the pump source whereas, in semiconductor lasers, electrical energy is used as the pump source. In semiconductor lasers, a p-n junction of a semiconductor diode forms the active medium or laser medium. The optical gain is produced within the semiconductor material [32].

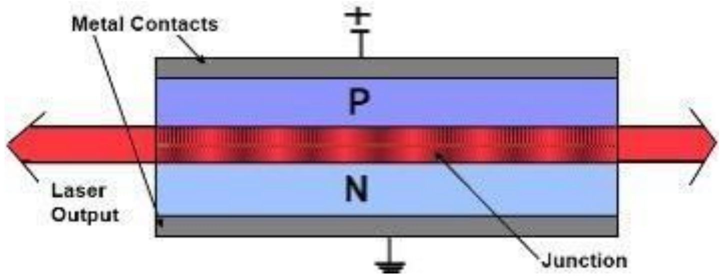

Figure (2.4): Semiconductor laser [32]

Advantages of laser

Following are the benefits or advantages of laser [33, 34]:

- It has high information carrying capacity and hence is used in communication domain for transmission of information.
- It is free from electro-magnetic interference. This phenomenon is used in optical wireless communication through free space for telecommunication as well as computer networking.
- It has very minimum signal leakage.
- Laser based fiber optic cables are very light in weight and hence are used in fiber optic communication system.
- It is less damaging compare to X-rays and hence widely used in medical field for treatment of cancers. It is used to burn small tumors on eye surface and also on tissue surface.
- High intensity and low divergence of laser is used for knocking down the enemy tank with accurate range determination. For this purpose neodymium and carbon dioxide laser types are used. Laser range finder is also used in several defense areas for medium range up to 10 Km.
- Single laser beam can be focused in areas smaller than 1 micro diameter. One square micro area is needed to store 1 bit of data. This helps in storing 100 million data in one square cm.Due to this fact, laser is being used in laser CDs and DVDs for data storage in the form of audio, video, documents etc.

Disadvantages of laser

Following are the drawbacks or disadvantages of Laser [35, 36].

- It is expensive and hence more expenditure to the patients requiring laser based treatments.
- It is costly to maintain and hence more cost to doctors and hospital management.
- Increases complexity and duration of the treatment based on laser devices or equipment.
- Lasers cannot be used in many commonly performed dental procedures e.g. to fill cavities between teeth etc.
- Laser beam is very delicate to handle in cutting process. The slight mistake in adjusting distance and temperature may lead to burning or discoloring of the metals. Moreover it requires higher power during the cutting process.
- It is harmful to human beings and often burns them during contacts.

Parts of laser

All lasers consist of three components:

1. An external pump source
2. The active laser medium
3. The resonator

The pump source guides external energy to the laser.

The active laser medium is located on the inside of the laser. Depending on the design, the laser medium can consist of a gas mixture (CO2 laser), of a crystal body (YAG laser) or glass fibers (fiber laser). When energy is fed to the laser medium through the pump, it emits energy in the form of radiation. The active laser medium is located between two mirrors, the "resonator". One of these mirrors is a one-way mirror. The radiation of the active laser medium is amplified in the resonator. At the same time, only a certain radiation can leave the resonator through the one-way mirror. This bundled radiation is the laser radiation [37].

External pump source

Laser pumping is the act of energy transfer from an external source into the gain medium of a laser. The energy is absorbed in the medium, producing excited states in its atoms. When the number of particles in one excited state exceeds the number of particles in the ground state or a less-excited state, population inversion is achieved. In this condition, the mechanism of stimulated emission can take place and the medium can act as a laser or an optical amplifier. The pump power must be higher than the lasing threshold of the laser. The pump energy is usually provided in the form of light or electric current, but more exotic sources have been used, such as chemical or nuclear reactions [38].

Optical pumping cavities

A laser pumped with an arc lamp or a flash lamp is usually pumped through the lateral wall of the lasing medium, which is often in the form of a crystal rod containing a metallic impurity or a glass tube containing a liquid dye, in a condition known as "side-pumping." To use the lamp's energy most efficiently, the lamps and lasing medium are contained in a reflective cavity that will redirect most of the lamp's energy into the rod or dye cell [39].

Various laser pumping cavity configurations. In the most common configuration, the gain medium is in the form of a rod located at one focus of a mirrored cavity, consisting of an elliptical cross-section perpendicular to the rod's axis. The flashlamp is a tube located at the other focus of the ellipse. Often the mirror's coating is chosen to reflect wavelengths that are shorter than the lasing output while absorbing or transmitting wavelengths that are the same or longer, to minimize thermal lensing. Often, the lamp is surrounded by a cylindrical jacket called a flow tube. This flow tube is usually made of a glass that will absorb unsuitable wavelengths, such as ultraviolet, or provide a path for cooling water which absorbs infrared [40].

Pumping with a single lamp tends to focus most of the energy on one side, worsening the beam profile. It is common for rods to have a frosted barrel, to diffuse the light, providing a more even distribution of light throughout the rod. This allows more energy absorption throughout the gain medium for a better transverse mode. A frosted flow tube or diffuse reflector, while leading to lowered transfer efficiency, helps increase this effect, improving the gain [41].

Electrical pumping

Electric glow discharge is common in gas lasers. For example, in the helium–neon laser the electrons from the discharge collide with the helium atoms, exciting them. The excited helium atoms then collide with neon atoms, transferring energy, as figure (2.5). This allows an inverse population of neon atoms to build up. Electric current is typically used to pump laser diodes and semiconductor crystal lasers (for example germanium).Electron beams pump free electron lasers and some excimer lasers [42].

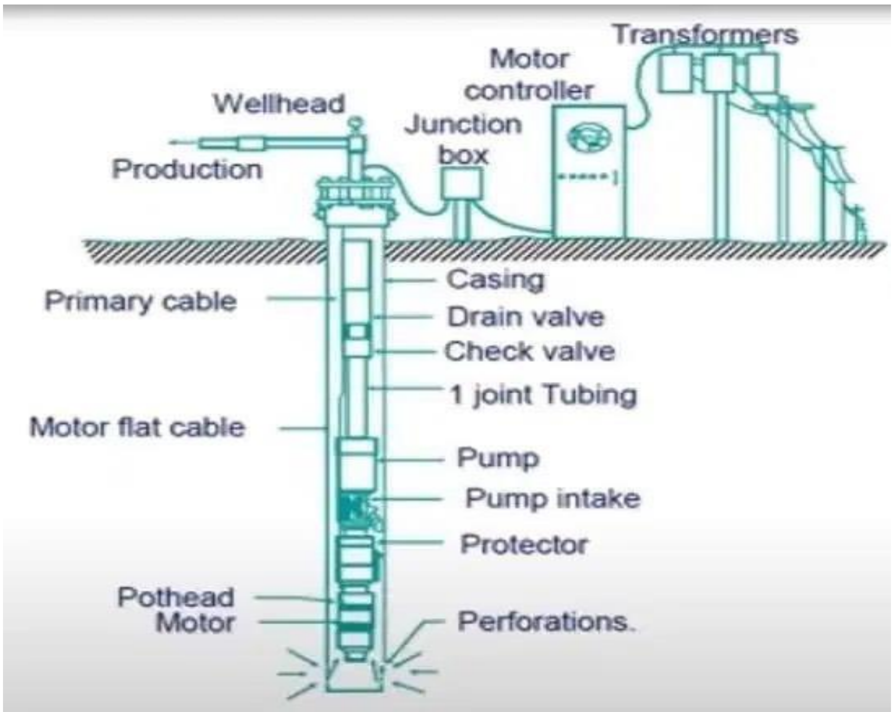

Figure (2.5): Electrical pumping [42].

Gas dynamic pumping

Gas dynamic lasers are constructed using the supersonic flow of gases, such as carbon dioxide, to excite the molecules past threshold. The gas is pressurized and then heated to as high as 1400 kelvins. The hot gas has many molecules in the upper excited states, while many more are in the lower states. The rapid expansion causes adiabatic cooling, which reduces the temperature to as low as300K. This reduction in temperature causes the molecules in the upper and lower states to relax their equilibrium to a value that is more appropriate for the lower temperature. However, the molecules in the lower states relax very quickly, while the upper state molecules take much longer to relax. Since a good quantity of molecules remain in the upper state, a population inversion is created, which often extends for quite a distance downstream. Continuous wave outputs as high as 100 kilowatts have been obtained from dynamic carbon dioxide lasers [43].

Similar methods of supersonic expansion are used to adiabatically cool carbon monoxide lasers, which are then pumped either through chemical reaction, electrical, or radio frequency pumping. The adiabatic cooling replaces bulky and costly cryogenic cooling with liquid nitrogen, increasing the carbon monoxide laser's efficiency. Lasers of this type have been able to produce outputs as high as a gigawatt, with efficiencies as high as 60% [44].

Active laser medium

The active laser medium is the source of optical gain within a laser. The gain results from the stimulated emission of photons through electronic or molecular transitions to a lower energy state from a higher energy state previously populated by a pump source.

Examples of active laser media include:

*Certain crystals, typically doped with rare-earth ions (e.g. neodymium, ytterbium, or erbium) or transition metal ions (titanium or chromium); most often yttrium aluminium garnet ($Y_3Al_5O_{12}$), yttrium orthovanadate (YVO_4), or sapphire (Al_2O_3) [45] and not often Caesium cadmium bromide ($CsCdBr_3$)

*Glasses, e.g. silicate or phosphate glasses, doped with laser-active ions [46]

*Gases, e.g. mixtures of helium and neon (HeNe), nitrogen, argon, carbon monoxide, carbon dioxide, or metal vapors [47].

*Semiconductors, e.g. gallium arsenide (GaAs), indium gallium arsenide (InGaAs), or gallium nitride (GaN) [48].

*Liquids, in the form of dye solutions as used in dye lasers [49].

In order to fire a laser, the active gain medium must be in a nonthermal energy distribution known as a population inversion. The preparation of this state requires an external energy source and is known as laser pumping. Pumping may be achieved with electrical currents (e.g. semiconductors, or gases via high-voltage discharges) or with light, generated by discharge lamps or by other lasers (semiconductor lasers). More exotic gain media can be pumped by chemical reactions, nuclear fission,or with high-energy electron beams [50].

The Resonator

The shape of a laser beam is determined by the resonator cavity in which the laser light is amplified in a gain medium, as figure (2.6). Laser resonators are typically formed by using highly reflective dielectric mirrors or a monolithic crystal that utilizes total internal reflection to keep light from escaping [51].

Below is a list of common laser resonator geometries [52]:

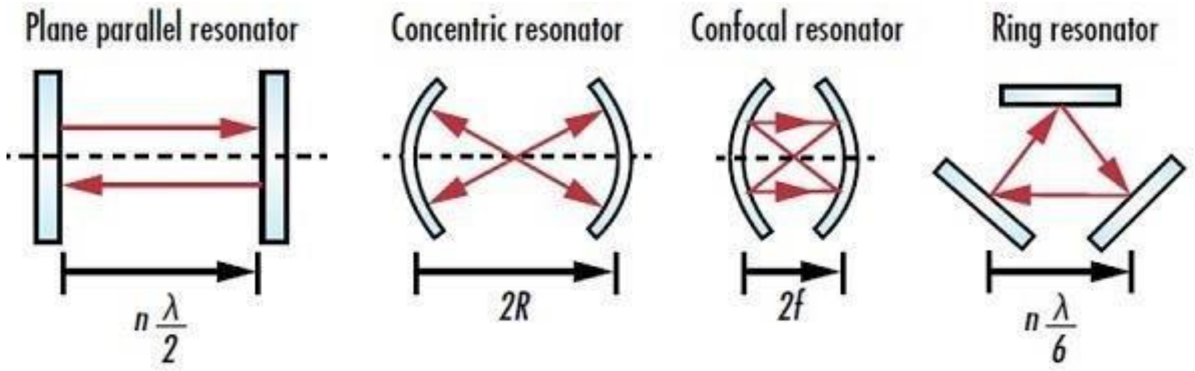

Figure (2.6): Resonator [51].

*Plane parallel resonator: two flat mirrors separated by a distance equal to an integral multiple of one half of the lasing wavelength

*Concentric resonator: two spherical mirrors with the same radius of curvature and coincident centers of curvature

*Confocal resonator: two spherical mirrors with the same radius of curvature and coincident focal points

*Ring resonator: ring of more than two reflectors where the total closed loop path of the reflected light is equal to an integral multiple of one half of the lasing wavelength

Resonator cavities are “stable” if the reflected light stays inside the cavity, even as the number of reflections approaches infinity .In this instance, the only way for light to leave the cavity is through a partially reflective mirror. On the other hand, resonator cavities are considered “unstable” if the reflected light continuously diverges as the number of reflections approaches infinity. When this occurs, the beam size will grow until it is larger than the reflectors and then escape the system. Stable resonators are often used with lasers that have powers up to 2kW to achieve high gain and improve directionality. Unstable resonators are typically used with higher power lasers to reduce the chance of damaging the reflectors [52].

Application of laser

Lasers are used for a variety of applications in scientific, medical, industrial, and commercial fields. In this section, we will describe some of the most significant applications of lasers in these categories, as well as some of the scientific figures who developed these applications. As we will see, the output power and wavelength of a laser determines the kind of applications for which it is most appropriate [53].

Scientific applications

Laser Spectroscopy

Laser spectroscopy is a branch of spectroscopy in which a laser is used to illuminate the sample being studied in order to determine a precise absorption spectrum. Due to their high degree of monochromaticity, lasers output a much narrower band of wavelengths than conventional light sources, allowing researchers greater precision in identifying the precise wavelengths that have been absorbed. In the described configuration involving a

Ti:Sapphire laser with a 30-second scan at a uniform rate, a detection of absorption 20.37 seconds after the start of the sweep would indicate an absorption wavelength of 760.37 nm. Infrared absorption spectroscopy, involving wavelengths of a few micrometers, is a reliable technique for identifying organic compounds. This is because molecules are commonly identified by their patterns of vibration and rotation, and the frequencies of infrared light match the vibrational and rotational frequencies of most molecules, resulting in absorption, as figure (2.7). Laser sources are available in the infrared region, but non-laser sources are easier and less costly to use when the extremely high resolution of laser sources is not essential [53].

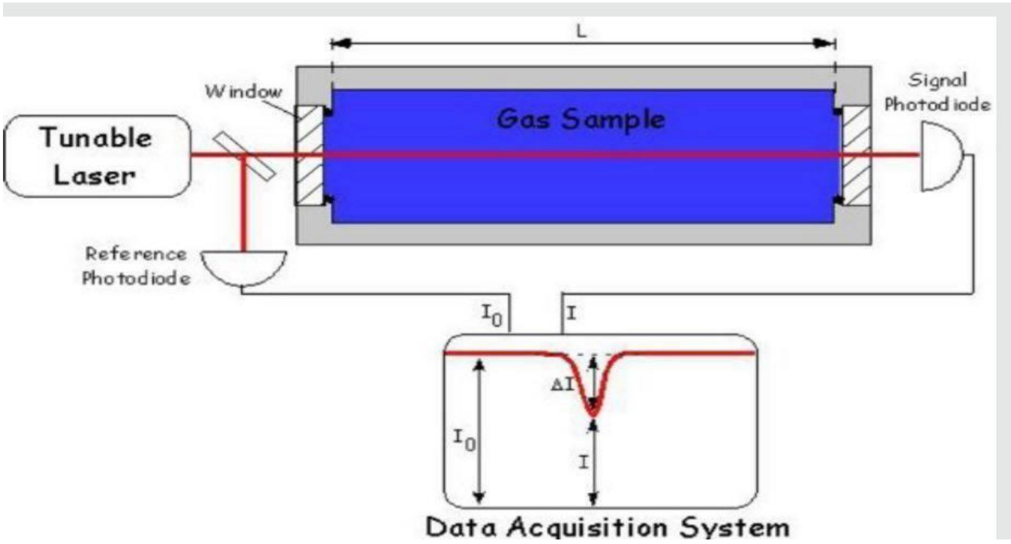

Figure (2.7): Laser Spectroscopy [53]

Confocal Laser Scanning Microscopy

Lasers can also be used as part of microscopes, although the manner in which an image is formed is very different from a conventional microscope. Confocal laser scanning microscopy, or CLSM, is a technique that reconstructs a three-dimensional rendition of the specimen. First, a laser beam is focused onto a single point on a two-dimensional "slice" of the sample to be imaged.

Mirrors are then used to scan the laser back and forth everywhere along that two-dimensional plane. A functioning confocal laser scanning microscope was first demonstrated in 1969 by M. David Egger and Paul Davidovits at Yale. Egger would go onto publish the first recognizable images of cells in 1973. Advances in both computer and laser technology in the following decades, coupled with new algorithms for digital manipulation of images, led to a growing interest in confocal microscopy, as figure (2.8). The first commercially available instruments utilizing this technique began to appear in 1987[54].

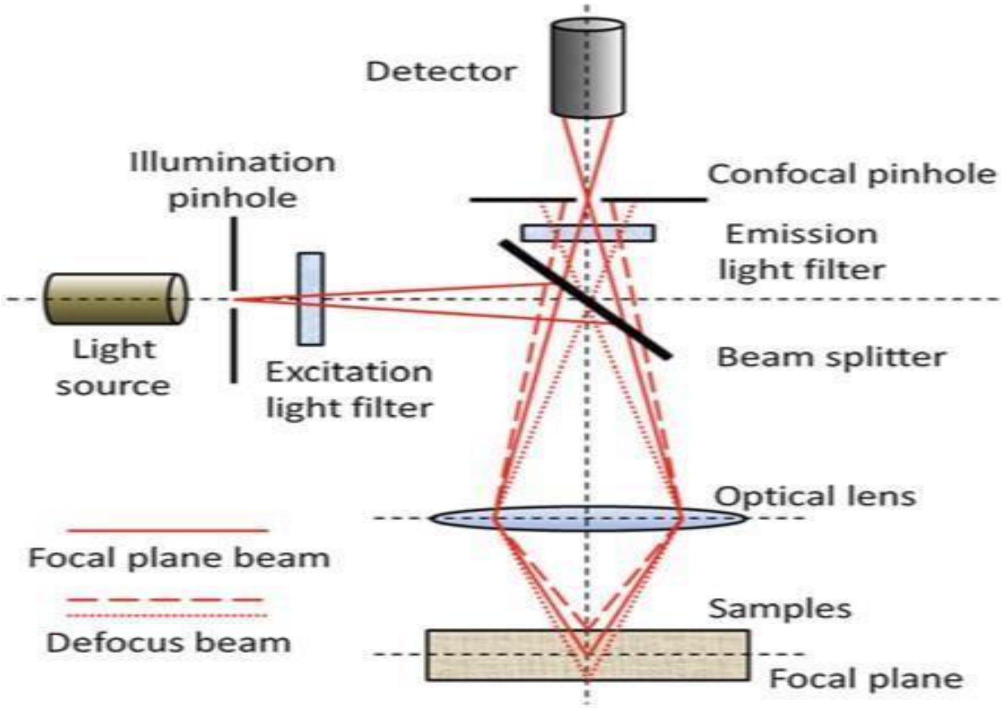

Figure (2.8): Confocal Laser Scanning Microscopy [54].

Optical Tweezers

Laser light is not only useful for probing matter at microscopic length scales, it can also be used to confine matter for experimental purposes. In 1970, Arthur Ashkin at Bell Laboratories first reported on the ability of laser light to exert forces on microscopic particles. This discovery led to the development of optical tweezers, which are scientific instruments that use a tightly focused beam of laser light to hold microscopic particles stable in three dimensions. Optical tweezers rely on the fact that photons have momentum. As we discussed earlier in the guide, when light is transmitted through an object, it refracts and changes direction. This change in direction corresponds to a change in momentum of the photon. According to momentum conservation, the object acquires a change in momentum that is equal and opposite to that of the photon. Optical tweezers have been used to sort cells, track the movement of bacteria, and measure piconewton-scale forces on microscopic particles, as figure (2.9). A primary application of optical tweezers is studying the properties of DNA. A strand of DNA can be attached to a glass or polystyrene bead that is then "gripped" by the optical tweezers. By pulling on the bead, scientists have measured the elasticity of DNA as well as the amount of force needed to break bonds within a DNA molecule. The researchers concluded that enzymes within the cell must act as "molecular motors" that are capable of exerting forces on the DNA strand [55].

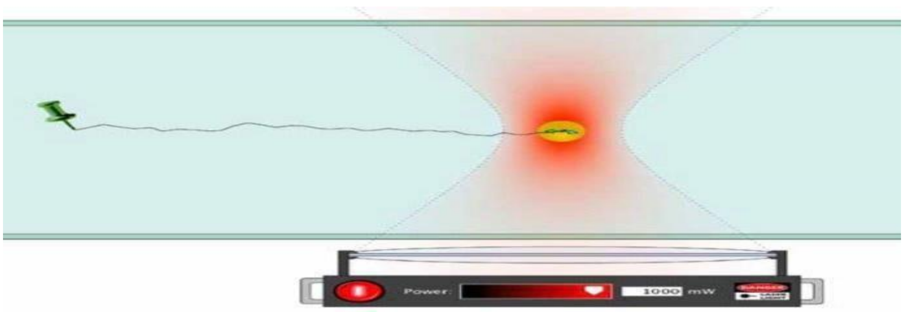

Figure (2.9): Optical Tweezers [55]

Medical Applications

The most important component of biological tissue is water, which absorbs strongly in the infrared range of the electromagnetic spectrum. In fact, water is such a strong absorber of infrared and accounts for so much of the bulk of soft tissue that it is a fair approximation to consider tissue as absorbing light as if it was water [56].

Laser Surgery

Carbon dioxide lasers are a common choice for laser surgery because they are readily available and emit 10.6- µm wavelength light that is easily absorbed by tissue. A CO2 laser beam focused on tissue at a sufficiently high intensity will cause cells to be vaporized due to energy absorption. Another advantage of the 10.6-µm CO2 laser wavelength is that it penetrates just deep enough into tissue to sealsmall blood vessels and stop bleeding. This cauterization effect makes the CO2 laser especially valuable for surgery in regions rich in blood vessels, such as the gums and the female reproductive tract, by giving the surgeon a tool to remove thin layers of blood-rich tissue. This is particularly useful in the treatment of gum disease and of endometriosis, a condition affecting several million American women. Carbon dioxide lasers also are used in a type of heart surgery that creates new paths for blood vessels in the heart, called transmyocardial revascularization. In fact, certain types of surgeries were only made possible with the introduction of the laser because they involved incisions that resulted in a high degree of bleeding with a conventional scalpel. Carbon dioxide lasers at 10.6 µm cannot be used to cut bone because bone contains less water than other tissue. Also the first type of laser refractive surgery, known as photorefractive keratectomy (PRK), uses an excimer laser to ablate material from the cornea after the top layer of the cornea, known as the epithelium, has been chemically wiped away. Concern over the effects of removing the epithelium led to the development of LASIK and it is currently the most common form of refractive surgery [56].

Lasers in dermatology

Laser dermatology procedures achieved early success in treating dark-red birthmarks called "port wine stains," which often appear on the face or neck. These discolorations result from blood in networks of abnormal blood vessels just under the surface of the skin. Because port wine stains tend to be spread over the surface of the skin, they cannot be treated by conventional surgery, and concealment with cosmetics was often the only solution. Dermatologists made early attempts to treat port wine stains using blue-green argon laser light, but these procedures were painful, worked only with dark blemishes, and could cause scarring, as figure (2.10). These problems were reduced by switching to pulsed dye lasers tuned to emit near the peak absorption of hemoglobin in blood at about 580 nm [57].

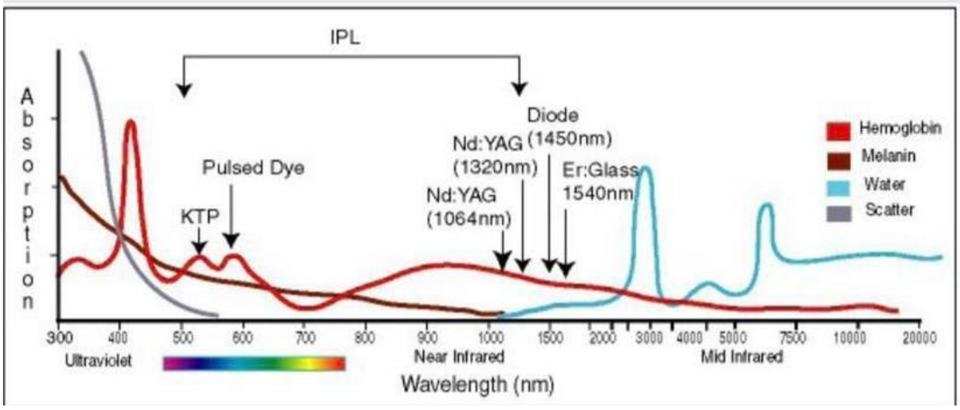

Figure (2.10): Lasers in dermatology [57]

Tattoo removal is another familiar medical application of lasers. Tattoos consist of colored ink that has been inserted Laser tattoo removal may be made easier due to a new family of encapsulated tattoo inks, which are designed for people who might have second thoughts. Laser skin resurfacing is another cosmetic procedure in which a carbon dioxide laser is scanned across aged areas, particularly the face, neck, and hands, to remove the surface layer. This process removes surface wrinkles and blemishes, thereby exposing a fresh layer of skin. Laser skin resurfacing requires a few weeks for the skin to heal and return to normal color. Lasers can also be used for the purpose of hair removal, which is accomplished by directing near-infrared laser light at hair follicles. A pigment called melanin in the hair and follicle absorbs the light, heating and killing the follicle, and thus stopping hair growth in areas where hair is undesired. The effectiveness of laser hair removal treatment depends on the contrast between skin and hair color; the darker, the hair and the lighter the skin, the more effective the treatment.It is more difficult to remove light- colored hair than dark-colored hair with laser light due to the lack of melanin pigment [58].

Laser dentistry

There are three primary applications of laser dentistry. Lasers can be used to “drill” teeth, using solid-state erbium lasers that emit 3-μm wavelength light. Although these lasers cannot remove solid enamel well, they can remove decayed areas and prepare cavities for repair. More important to both dentist and patient, laser pulses are less threatening than the traditional whirring mechanical drill and can be less painful as well, as figure (2.11). As mentioned earlier, carbon dioxide lasers can also be used to treat gum disease by removing swollen tissue. Laser teeth whitening is another popular cosmetic dental treatment that uses visible argon and neodymium lasers to activate a special gel solution that has been applied to the patient’s teeth [59].

Figure (2.11): Laser dentistry [59]

Conclusions

1. The laser device reflects light of a single color, that is, of one wavelength between the back mirror and the lens. This is done by stimulating the medium to produce that color of light, which is a characteristic of the selected crystal or medium. After the beam of light is reflected within the medium several times, the collected light waves reach an equilibrium position. Then it is characterized by the regularity of its phase (step) and comes out as a high-energy laser beam.

2. Medical lasers have laser diagnosis, laser therapy, treatment and treatment as well as photodynamic therapy.
3. A laser that gives an output of X-rays with a wavelength of up to 200 angstroms.

Future Works

1. The laser beam and its uses in various applications.
2. Laser in ophthalmology.
3. The use of lasers in industrial applications.
4. Modeling of a thulium laser in glass.
5. Water sterilization using a carbon dioxide laser

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