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Helium Neon Laser and its Uses in Medicine

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Abstract:

In this research, we discussed the laser, how it was developed, when it was discovered, what are the capabilities of the laser, the conditions for the occurrence of the laser, the principle of its operation, the characteristics of the laser, and finally the types of lasers. It also included the basic concept of the laser theory, its principle of operation, and the basic processes that occur during the interaction of the electromagnetic wave, as well as the basic processes in the electrical discharge of the gas. We also explained the properties of the laser, which include purity, high directionality, coherence toning, and also included the use of the laser in medicine. It included the helium-neon laser, its operating principle, components, advantages, and disadvantages.

Introduction:

The topic of laser has occupied a place in the discussion of various aspects of science and technology during the last ten years. Its use is not limited to physics and chemistry laboratories, but has become the modern and advanced face of many topics. For example, traditional lamps, both spectral and thermal, have been replaced by the laser source, and many methods, treatments, and theoretical and practical research have been developed in everything directly or indirectly related to the work of the laser, including, for example, the search for an effective medium and methods of pumping energy and ways to supply it and optical devices such as mirrors, lenses, light gratings, detectors, optical fibers, electronics, and many others [1].

Laser or light amplification by stimulated emission of radiation: It is electromagnetic radiation whose photons are equal in frequency and identical in wave phase, where their waves interfere constructively to transform into a light pulse with high energy and highly coherent in time and space with a very small divergence angle, which cannot be achieved using techniques other than stimulating radiation. [4][3[2][

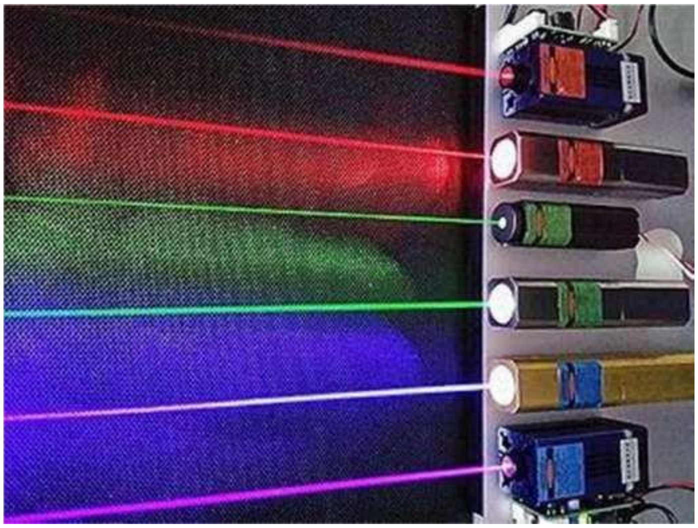

Figure (1-1) shows a semiconductor laser, which is one of the common sources of medium-power lasers, used in various fields, and available in different spectra.

History of laser development:

The story of the laser began a long time ago, and may extend to ancient myths expressing man's desire to obtain a decisive weapon whose ammunition is a beam of light. Figure (2-1) But the scientific history of lasers began in the middle of the nineteenth century. In 1819 AD, Hans "Oersted", a professor of physics at the University of "Copenhagen", organized the relationship between magnetism and electricity by observing the behavior of a magnetic compass needle when placed near a wire carrying an electric current. Then came the big step when the American scientist "Charles Townes" (1915-1964) emerged in the research arena. Townes began his research in 1951, and in 1953 he and his students discovered the "maser". Around 1957 he began thinking about making a maser that would emit infrared rays or light rays instead of microwaves. In 1958 he published a theoretical study on what is called the optical maser (laser). On July 7, 1960, the theory became a reality when Mayan announced the success of the first practical laser made of synthetic ruby. Since then, the name "laser" has been shining and branching out, opening the way for countless applications, and the future still hides many applications in its folds. Figure (3-1). Lasers have developed at an amazing speed, and their use in medicine has developed in order to perform operations and apply new methods to treat diseases. They have proven highly efficient in surgery in general, and in precise surgeries in particular, and today they have become widely used in medical branches. In 1917, physicist Albert Einstein was able to establish the theoretical foundations on which the laser works in his research on the photoelectric phenomenon. In this phenomenon, scientists noticed that when electromagnetic radiation is directed at a metal surface, electrons are emitted from this surface only if the light frequency exceeds a certain limit value. However, if the light frequency is less than that, electrons are never emitted, no matter how intense the light is (6).

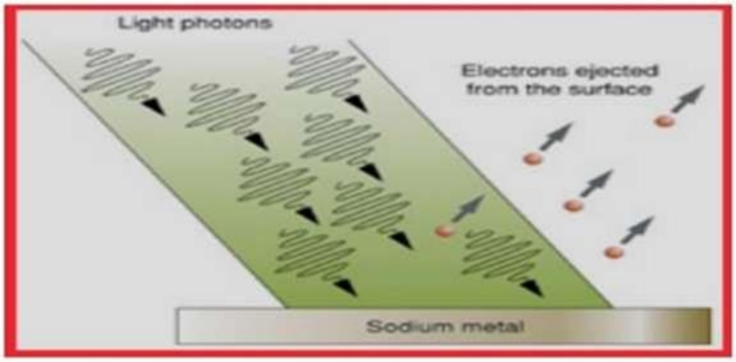

Figure (2-1) illustrates the phenomenon of electron emission when an electromagnetic beam is directed.

After the discovery of the first laser, many other types of lasers were discovered with great success. Solid-state lasers with four levels appeared before the end of 1960, which used uranium ions and rare earth metals. The numbers of these devices multiplied rapidly during the next two years. Among these lasers, the neodymium laser gained the greatest practical importance because it could be operated at room temperature, and also because these lasers could discharge power at a rate comparable to that of the ruby laser[7] .

Laser Components:

Every laser device, regardless of its type, contains three basic elements:

1- The active medium, which is the material responsible for generating the laser and which has the reverse distribution. Examples of active materials commonly used currently include:

- Solid crystals: such as synthetic ruby, aluminum agate, and glass called YAG.
- Gaseous materials: such as a mixture of helium and neon gases.
- Ionized gases: such as argon and krypton gases.
- Gaseous molecules: such as carbon monoxide and carbon dioxide gases
- Liquid dyes: These are various organic chemical dyes dissolved in water

Solid semiconductor materials: such as gallium arsenate[5]

2- Energy source: which determines the induction method to excite the active material and induce it to emit laser radiation... The energy sources currently used are diverse, including:

- Electrical energy: This is represented by the use of direct electrical energy in two ways, such as using radio frequency sources. R.F. as input energy or using electrical discharge in direct current, such as carbon dioxide gas laser - helium neon laser, argon gas laser... etc.
- Optical energy, known as optical pumping, can be emitted from two main sources:
- Using high-power incandescent lamps, such as ruby lasers.
- Using a laser beam as an energy source to another laser, the latter is commonly used in producing many laser radiations in different spectrum regions, such as commercially available liquid dye lasers.
- Thermal energy: Both the kinetic pressure of gases and changes in temperature can induce and excite materials to emit laser radiation.

- Chemical energy: Chemical reactions between a mixture of hydrogen H2 and fluorine F2 give energy causing these molecules to emit laser radiation, as well as with a mixture of deuterium fluoride DF and carbon dioxide. An example of this is chemical lasers[8] .

3- The resonator is the container and the activator of the magnification process, and in the material, it is used either:

- External resonator: It is two identical and parallel mirrors at the end of the tube containing the active material, and the multiple reflections between them are the basis for the optical magnification process as in gas lasers.
- Internal resonator: It is represented by coating the ends of the active material to act as a mirror as in ruby crystal lasers and in solid lasers in general.

In both cases, one of the mirrors must be completely reflective (100) of the light photons, and the other must be partially reflective (95), allowing (5%) of the light falling on it to pass through so that the laser beam can exit from it[9] .

Conditions for the occurrence of lasers:

In order for laser devices to work, they must have three basic conditions:

First: The presence of the active medium. The basic rule for the operation of the laser is a system with a large number of atoms, molecules or ions that emit a spectrum, part of which falls in the visible range of electromagnetic radiation. We often talk about the active medium as if it were a group of gas atoms, but the atoms, molecules or ions of the substance in its liquid or solid state also form an active medium in important types of lasers. Second: - The occurrence of the reversed population, and the emission of laser rays requires working to increase the number of atoms in the higher energy levels, i.e. increasing their population from the natural state in them by using external energy, for example, and when the number of atoms in the higher energy levels is more than the number of atoms in the lower energy levels, we can say that a reversal in the population or the reversal of the population has occurred, which we called the reversed population, and under these conditions the probability of stimulated emission is high, and it is possible to obtain photons that are linked in phase with each other as shown in Figure (5-1)[8] .

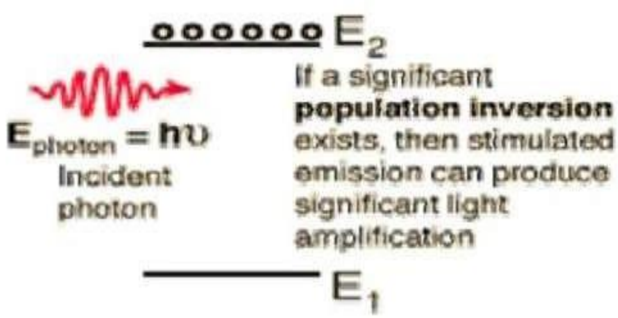

Figure (5-1) shows the inverse enumeration[8] .

Third: Feedback is a necessary condition for the emitted radiation to take its correct oscillation and thus lead to obtaining a beam of rays with a high degree of directivity and coherence. Without this condition, the laser only works as an amplifier for a narrow light beam and loses the aforementioned features that made it a light source with special benefits. This condition can be achieved by using a resonant cavity with a suitable design called a resonator. The first successful resonator design used for stimulated emission radiation in the visible range is the Gabrí-Pérot interferometer, which consists of two parallel plane mirrors with the active material placed between them. If one of the mirrors is made partially transparent, a useful part of the stimulated radiation with a uniform direction parallel to the axis of the two mirrors represents the laser product. [1] When the three conditions above are met, there remains a condition that revolves around the subject as a whole and is important for the operation of both the maser and the laser. It is called the threshold condition. The requirements of this condition must be met for the amplification process in the active medium to begin, and then the oscillation process in the resonator. The reason for this is that laser devices, like any practical devices, are not ideal, and include many causes of loss and dissipation. They are generally low-efficiency devices when compared to other practical devices[1] .

The working principle of the laser:

In 1917, Einstein studied the interaction of electromagnetic waves, or what is called (radiation) in short, with the atoms of matter and found that there are three types of interactions, which are:

A- Absorption: In which the atoms of matter absorb the photons of radiation directed at them, and the energy of the absorbed radiation works to raise the electrons from low-energy orbits to high-energy orbits, and the atoms become in an excited state. Photons are not absorbed by matter unless their energy exceeds the energy difference between the electron orbits of the atoms of that matter. Therefore, materials are transparent to all radiations whose frequencies are less than specific values determined by the atomic structure of those materials, as is the case with glass[8] .

Figure (6-1) shows the transition of an electron from one energy level to a higher energy level . [8]

B- Spontaneous Emission: In this, excited atoms emit electromagnetic waves as a result of electrons descending from high-energy orbits to low-energy orbits. The spontaneous radiation emitted by the excited material is called noncoherent radiation because the electrons descend on their own and in a random manner between the different orbits of the atom. Therefore, this radiation contains a very large number of frequencies. Normal light sources depend on the phenomenon of spontaneous emission in their work[8] .

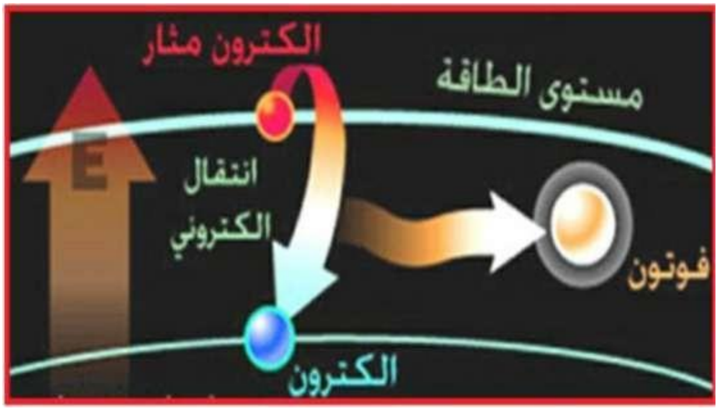

Figure (7-1) shows how a photon is emitted when an electron moves from a higher energy level to a lower energy level.[8]

C- Stimulated Emission: In this, the excited atoms radiate electromagnetic waves as a result of the electrons descending from high-energy orbits to low-energy orbits, but not in a spontaneous and random manner as in spontaneous emission, but as a result of stimulating them with radiation of a specific frequency. The stimulated radiation emitted by the excited material is called coherent radiation because the electromagnetic waves resulting from the descent of electrons have a frequency and phase that are exactly equal to the frequency and phase of the waves that stimulated the electrons to radiate, and therefore this radiation has one frequency theoretically. The frequency of the radiation emitted by the material can be calculated by dividing the energy difference between the two orbits between which the electron moved by Planck's constant[6] .

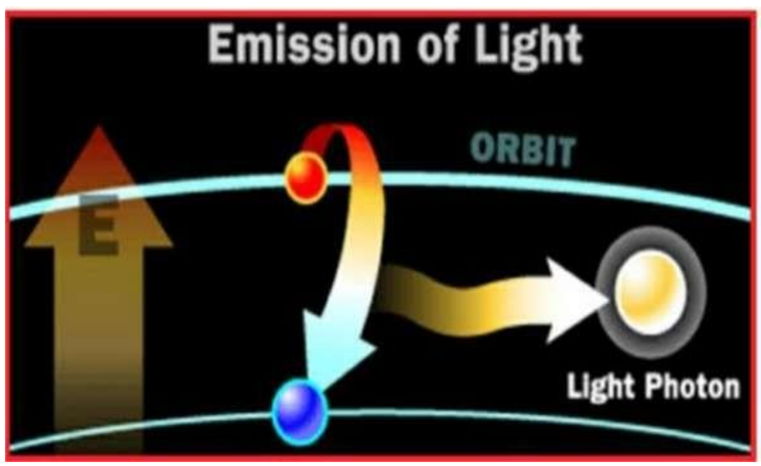

Figure (8-1) shows the frequency of the radiation emitted by the material through the energy difference between the two orbits between which the electron moved[6]

Laser characteristics:

The laser beam has four basic features: -

1. Monochromatic (single frequency) means that the laser beam has only one wavelength, i.e. a single frequency.
2. Coherency means that the difference between any two points on the laser beam wave is constant when the beam moves in time and space. The laser is the only light source that has the characteristic of coherence compared to other traditional sources.

3. Directionality: The beam spreads in one direction and for very long distances without divergence from its axis or a very small divergence that does not exceed a few centimeters per kilometer.
4. Brightness: This means that the power density of the laser beam per unit area is very high. The power density of the laser beam per unit area is called intensity. For example, the intensity of a normal tungsten lamp with a power of (100 W) is about (2000 W/cm2), while the intensity of a laser beam with the same power reaches about (2×10^9 W/ 〖cm〗 ^2), which is one million times greater than a normal tungsten lamp[10] .

Types of lasers:

The types of lasers that we will refer to are only a few examples of the many that we were unable to address or refer to, and the information that we will mention about the laser's output in terms of energy, power, and pulse duration are only amounts that have become estimates today due to the rapid development that must have addressed these amounts for their practical importance[1] .

Among these lasers: -

First: Solid State Lasers:

Solid State Lasers:

Solid material lasers usually mean those lasers in which the active medium is either an insulating crystal or glass. Solid state lasers often have active materials that are impurity ions inside ionic crystals. The ion is usually one of the compounds from the transition elements series in the periodic table (for example, transition metal ions, most notably Cr^{+3}, or rare earth ions, most notably Nd^{+3} and Ho^{+3}).

The transitions that occur in laser work include states that return to the inner layers, but these transitions are not strongly affected by the crystal field. This in turn means that these transitions are very sharp. The radiating channels are somewhat narrow, and therefore the threshold limit for the pumping rate [$CO(v-n)+CO(v-m)\rightarrow CO(v-n+1)+CO(v-n+1)$] for the four-level laser is small enough to allow the laser action to start[11]

Solid state lasers include:

1- Ruby laser:

The ruby laser is the first type of laser and is still used today. Ruby has been known for hundreds of years as a natural gemstone and consists of a crystal (Al_2O_3 Corundum) and Cr^3 ions have replaced some Al^3 ions. The laser material is obtained by growing the crystal from a molten mixture of Cr_2O_3 (~0.05% by weight) and Al203. The energy levels of the laser are the chromium ion levels in the crystal structure of Al_2O_3. [11]

2- Neodymium lasers:

Neodymium lasers are the most common solid-state lasers. The laser medium consists of either a Y3A15O12 crystal (usually called YAG, the word YAG is made up of the first letters of Yttrium aluminum garnet) in which a portion of Y^3 ions are replaced by Nd^{+3} ions, or, more simply, glass doped with Nd^{+3} ions. Neodymium lasers can oscillate in several lines, the strongest and most widely used of which is the 1.06 = (λ) micrometer line[11] .

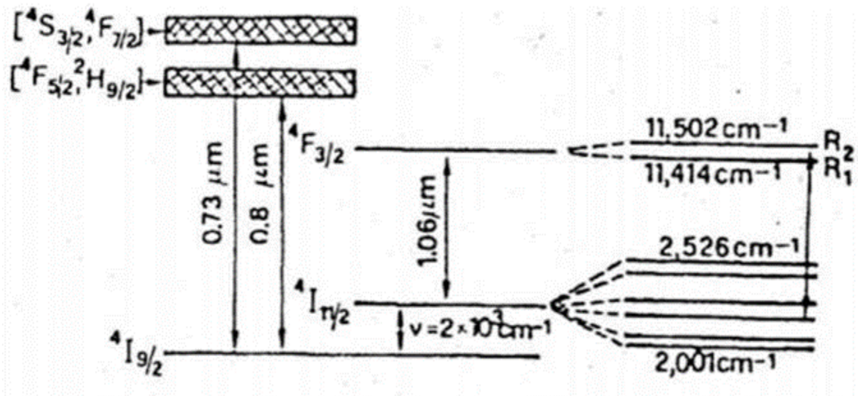

Figure (12-1) shows a simplified diagram of Nd: YAG energy levels[11]

Second: Liquid lasers (dy lasers) (Liquid laser (dy laser:

The liquid lasers that we will study are those in which the active medium consists of solutions of certain compounds of an organic dye dissolved in liquids such as ethyl alcohol, methyl alcohol, or water. These dyes usually belong to one of the following categories:

a) Polymethine dyes (micrometer) 1_0.7

b) Xanthene dyes (micrometer) 0.7_0.5

c) Dyes (micrometer) 0.5_0.4

d) Flash dyes (micrometer) 0.4>(λ)

Because of the possibility of tuning their wavelengths and the wide coverage of the spectrum, dye lasers play an important and increasing role in applications in various fields and areas including (study of spectra and photochemistry). [11]

Third: Chemical Lasers:

A chemical laser is usually defined as a laser in which the housing inversion occurs directly by chemical reaction. According to this definition, the CO2 gas dynamic laser cannot be considered a chemical laser. Chemical lasers usually use the chemical reaction between gaseous elements. In this case, a large part of the chemical reaction is left in the form of vibrational energy of the molecules. Therefore, the laser transitions are often of the rotational vibrational type (the only exception that may be worth mentioning is the photochemical dissociation laser) and the corresponding wavelengths available at present are between 3 and 10 micrometers. These lasers are important for two main reasons:

a) These lasers provide an important example of the direct conversion of chemical energy into electromagnetic energy.

b) Since the amount of energy available in a chemical reaction is very large, the external powers are expected to be high.

Examples of these lasers are: -

HF laser: This laser oscillates on several rotational vibration lines in the range of 2.6 to 3.3 micrometers and gives continuous output powers up to 10KW and pulse energies up to a few kilojoules with a chemical efficiency of up to about 10%. [11]

Fourth:

Invasive Laser: Many gases are used to produce the laser beam, and they are used for many purposes. He_Ne helium-neon laser, which emits in a variety of waves in the range of 633 nanometers, is popular in education due to its low cost[12] .

Laser Theory:

In the case of two energy levels (E2-E1) of a certain material in which the number of atoms per unit volume is (N2, N1) respectively, and a flux of photons (ϕ) with energy (E2-E1) falls on this material in the direction of the (Z) axis as in Figure (2-2) and the thickness of the material is (dz), the change in the value of the flux of these photons (ϕ) either results from the absorption of energy or stimulated emission (assuming the neglect of spontaneous emission), as in the equation [2] dϕ/dz=σϕ(N2,N1) (2-6a) This equation shows that this material behaves as a medium that amplifies the flux of photons (ϕ) for the thickness of the material (dz) when the condition (N2 > N1) is met, i.e. [2] (2-6b) dϕ/dz > 0

In this case, the flux of photons coming out of the medium increases.

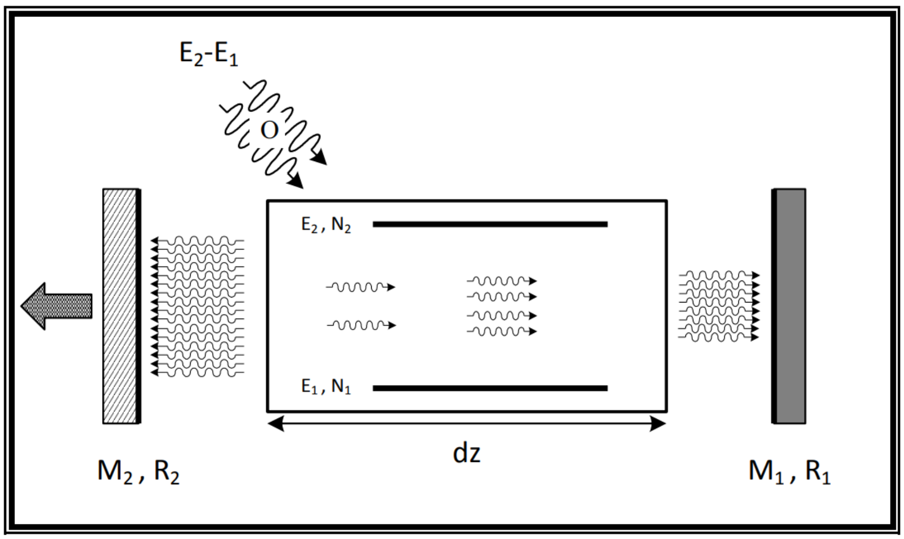

Figure (2-2) A diagram showing the amplification process in the active medium of the laser.

If (N2 > N1), the substance behaves as an absorber. In the case of thermal equilibrium (at room temperature, for example), N2 is always less than N¬1 according to the Boltzman distribution according to the following equation [3]

N_2/N_1=exp [-(E_2-E_1/K_B T] (2-7)

Where T is the absolute temperature (K), KB is the Boltzmann constant (1.38×10^(-23) J/K)

The condition N1>N2 is the inversion population condition and the material whose energy levels in the atoms or molecules that make it up can be an effective medium to produce an inverted distribution (medium Active).

In general, the inverted distribution between the energy levels of the material occurs through pumping processes that are carried out by electromagnetic waves (a light source or another laser), or electron collision, or collision between two similar or different molecules, or by a specific chemical reaction.

The photonic oscillation process (Photonic oscillation) requires feedback to maintain the oscillation. Feedback in the laser system is done using an optical cavity called a resonator, which consists of two mirrors between which the generated photons travel back and forth (Resonator) along the optical axis of the cavity.

By integrating Equation (2-6a), the amount of gain in the photon flux can be described by the following equation [2]: $\int_0^{\emptyset} \frac{d\emptyset}{\emptyset} = \int_0^{L} \sigma(N_2-N_1)dz$ (2-8)

Where L represents the length of the effective medium, (N_1-N_2) is the value of the inverse distribution between the laser energy levels. Taking into account the losses due to the reflectivity of the optical resonator mirrors, the oscillation occurs when the threshold condition is met, which is given as follows [2]

R_1R_2 exp(2□□(N_2-N_1) L) =1

R_1R_2 exp(gL) =1 (2-9)

Where R_1 and R_2 are the reflectivity of the front and rear mirrors respectively, and g is the gain per unit length.

If one of the mirrors is fully reflective (the rear mirror), i.e. 1 = R_2 and the other is partially reflective (the front), then the limit R_1R_2 can be expressed by the total reflectivity R, and equation (9-2) becomes as follows: R exp(2□□(N_2-N_1) L) =1 (2-10)

There is a critical value for the inversion population distribution (inversion population Critical) at a certain value of reflectivity (R) at which or above it begins Oscillation of the laser beam, and this value is given by the following equation: [2] (N_2-N_1) = -Ln(R)/2□L (2-11)

A spontaneously emitted photon (z) perpendicular to the axis of the optical cavity mirrors can cause the stimulated emission process necessary to start the oscillation of the laser beam.

Gas Laser Pumping:

Electrical discharge in gas

Electrical discharge in gas can be classified into three types depending on the value of the electric current passing through the discharge space as follows [40] :

1. Dark discharge or Townsend discharge where the discharge current value is around 10^{-6} ¬¬¬A
2. Glow discharge where the discharge current value is around 10^{-6} ¬¬¬-0.1 A
3. Arc discharge where the discharge current value is around 0.1 A or more. If the gas pressure does not exceed a few millimeters of mercury, it is very likely that a glow discharge will occur when the gas breakdown occurs. The value of the electric discharge current passing is around a few milliamps when a potential difference close to the gas breakdown voltage is applied. If the pressure is high (close to atmospheric pressure) and the resistance of the external circuit is low, the gas can be blown out, and the current is determined primarily by the discharge in the external circuit, and the discharge voltage is low (about several tens of volts). Glow discharge can also be obtained at or above atmospheric pressure with a discharge current greater than 1A, but the glow discharge turns into an arc region if either the pressure or the current increases. A current of suitable value is passed through the gas, where free ions and electrons are produced, which are accelerated by the electric field applied between the electrodes and obtain additional kinetic energy that enables them to excite other neutral atoms by collision. The movement of electrons is more important than the movement of ions in the process of excitation by collision due to their smaller mass [41-42]. The rate of kinetic energy of electrons is much greater than the rate of kinetic energy of ions in the case of low gas pressures. The process of electrical pumping in a gas is usually the result of the collision of electrons with molecules in the ground state (A) as follows [14] [41: [$A + e \rightarrow A^* + e$ (2-19) Where *A represents the molecule in the excited state

It occurs in a gas composed of one type of molecules, but if the gas consists of two types of molecules, the excitation process occurs as a result of collisions between molecules of the two different types, and this process is called resonance energy transfer (Transfer Energy Resonance). If the molecules of the first type are in the excited state and the molecules of the second type are in the ground state and the energy difference between them is less than the value (KT), the molecules of the first type may return to the ground state while the molecules of the second type move to the excited state as follows [14] [42: [$A^* + B \rightarrow A + B^* + \Delta E$ (2-20)

This process can be used to pump molecules of the second type (B) if the excited state of the molecules of the first type (A) is metastable, i.e. the radiative transition to the ground state is not allowed. After the molecules of the first type (A) are excited to the upper level by colliding with the electrons, they will remain in it for a long time, thus forming an energy reservoir that can be used to excite the molecules of the second type [2] (B)

Basic Processes in Gas Electrostatic Discharge:

Energy exchange between gas particles occurs mainly through collisions, which are classified into several different types. One type of collision is the elastic collision, in which only kinetic energy is exchanged. Most collisions in gases are of the elastic type, and the reason for this is that the atomic or molecular structure of the gas does not change [40].

Inelastic collisions include the exchange of excitation energy or ionization energy (or dissociation energy in molecular gases) in addition to kinetic energy. Therefore, an electron that collides with a neutral atom can excite that atom and thus increase its potential energy at the expense of decreasing the kinetic energy of the electron [43]. Electrons and ions take energy from the applied electric field and transfer it through collisions with other particles. The energy transfer in the collision is very large because the mass is close in both of them. As for the electrons, they transfer energy between them effectively through collisions that take place away from the cathode region. Electrons take more energy from the electric field than ions do because of their smaller mass and greater drift velocity.

There are seven collision and radiation processes that affect the distribution of atoms or molecules in the electrically excited levels [14.] These processes are vibrational excitation of CO_2 and N_2 in CO_2 lasers, vibrational excitation and de-excitation of electrons, resonant energy transfer between N_2 and CO_2 molecules vibrating in asymmetric stretch mode, collisional excitation and de-excitation by atoms and molecules, vibrational excitation and de-excitation of N_2, excitation and de-excitation by electrons and heavy particles of CO_2 molecules vibrating in symmetric stretch and bending modes, spontaneous emission of CO_2, and finally stimulated emission at wavelength [14][11](10.6μm)

There is an opposite process to every collision process, as the energy of excitation can be transferred to the electron when it collides with a previously excited particle, and then the electron will have a higher energy than before the collision process, and these collisions are completely elastic. If the energy of the electron is high enough, it will liberate another electron from the atom through the collision process with another atom, which ionizes it. The opposite process to this ionization process is the process of recombination, in which the electron is captured by a positive ion. The electron may also be captured by a neutral atom, and this process is called contact or association, and the opposite process is detachment. Excited atoms or ions can convert their excitation energy into photons through a radiative transition to a lower level, and the energy difference of this transition is equal to the energy of the emitted photon.

Laser Properties:

Laser beam properties: Collimation Spectral purity

1- Spectral purity:

It is the characteristic that represents the laser beam's proximity to a single wavelength characteristic. This characteristic is present in the laser more than in other traditional sources. The quantity that expresses the degree of this characteristic is the emission line exposure (Δv_o). This quantity depends on the light source and the highest energy level of the transition. The best value for (Δv_o) is zero, but this is not possible in pulsed lasers because:

The degree of monochomaticity is inversely proportional to the number of oscillating modes, and this can be overcome (the large number of oscillating modes) High spectral purity by operating the laser as a single-mode laser that was previously discussed, and also working on the stability of operation in this mode, and spectral purity is closely related to coherence

The figure shows a diagram of the Gaussian shape of the transverse mode TEM00 and some variables related to the Gaussian laser beam. It is clear from the figure that the laser beam reduction can be calculated by the following equation: w(z)=w_0 [1+(λz/ (πw_0^2)) ^2] ^ (1⁄2) (3-1)

And the radius of curvature

R(z)=z[1+((πw_0^2)/λz) ^2] ^ (3-2)

2-High directivity Directionality

It is one of the characteristics that has gained admiration and attention, as the beam has a very small expansion, meaning that the divergence angle is small compared to other light sources except semiconductor lasers. The degree of directivity is expressed by the divergence angle: which is the plane angle between the edge of the beam and its axis, as in the diagram above. The angle is determined using the laws of diffraction. According to the product of a laser that oscillates in the transverse formula TEM00, the laser divergence angle.

Θ=λz/(πw_0^) (3-3)

= 0.64 λ/D Θ (3-4)

D: is the diameter of the light source's aperture and is equal to 2ω_0

The divergence angle of the laser beam can be reduced by expanding the beam by passing the beam in the opposite direction through a telescope.

3- Brightness (Luminance)

The brightness characteristic is a quantity that depends on how the light emitted from the source is directed spatially, as well as on the ability of the source's output and on the response of the detector (the human eye) to light, since the eye only sees the visible part of the electromagnetic spectrum. The brightness of a light source is defined as the amount of energy emitted per unit time and per unit area of the surface within a unit of solid angle.

B=P/AΩ (3-5)

Where: P is the power of the source

A: Cross-sectional area

Ω: Solid angle

It appears that the intensity does not depend on the divergence angle

4- Tuning

It is the process of modifying the laser output in order to obtain, continuously and gradually, different wavelengths that fall within the emission range of the laser active medium

5- Specki pattern

It is a phenomenon specific to laser beams scattered from a rough surface, where the protrusions on the wall represent point sources. When constructive interference occurs A bright spot is formed, but if destructive interference occurs, dark spots are generated, which is also a characteristic of diffraction and has multiple medical applications.

6- Coherence

It is the characteristic of maintaining the waveform constant over time (spatial coherence). This occurs when the width of the spectral line is very small, and the difference between any two points on the wavefront is constant over time (temporal coherence).

1- Space coherence: The phase difference between any two points on the same front is constant over time

$l=L\lambda/S$ (3-6)

l: the length of the space coherence is related to the wavelength λ, the diameter of the laser source S, and r the area of the laser beam.

Temporal coherence: The frequency spreads at a single value for the frequency and by exposing the spectral line, i.e. the waves remain in one phase and for different wavelengths, the more the beam has a single wave color, the greater the temporal coherence becomes[1].

Uses of Lasers in Medicine:

The laser has become an increasingly important medical tool, after optical scalpels were used to treat cells or entire organs due to their ability to be highly selective, rather than just tools that cut anything they encounter. This specificity is what allows laser beams to penetrate inside a cell or a specific organ, while its appearance remains intact, which is something that no other surgical scalpel can do.

The improvement in the accuracy of these tools in recent decades has enabled the diversification of medical laser uses in more than one field. In the beginning, the heat generated by laser beams was used to destroy tissues. Now, although thermal effects are still the most commonly used. For medical purposes, other, non-thermal effects have also proven to be increasingly important in treatment and diagnosis. In addition to heating tissues, photons emitted from laser beams can trigger chemical reactions, break the atomic bonds that hold atoms together, or generate shock waves.

Uses of Lasers in Medicine:

Biomedical applications of lasers include many such works, such as removing arterial blockages, lasers are used to prevent blindness, stop gastrointestinal bleeding, perform various types of surgeries and clear blocked arteries, break down kidney stones, get rid of cataracts, skin diseases (acne - eczema - herpes simplex - scars and warts - burns) and others. It is also used in rheumatic diseases and sports medicine (rheumatoid arthritis - osteoarthritis - tendonitis - edema, etc.), and finally it is used in the mouth and teeth (tonsillitis - sinusitis - gingivitis - nerve inflammation - periodontal infections - osteomalacia). It has also been proven by scientific statistics that lasers are beneficial in raising the pain threshold during and after surgery, as it reduces bleeding, treats various lesions, and even changes genetic material. Lasers can provide scientists with information about vital processes that include biomedical applications of lasers, many such works, such as removing arterial blockages, lasers are used to prevent blindness, stop gastrointestinal bleeding, perform various types of surgeries and clear blocked arteries, break down kidney stones, get rid of cataracts, skin diseases (acne - eczema - herpes simplex - scars and warts - burns) and others. It is also used in rheumatic diseases and sports medicine (rheumatoid arthritis - osteoarthritis - tendonitis - edema, etc.), and finally it is used in the mouth and teeth (tonsillitis - sinusitis - gingivitis - nerve inflammation - periodontal infections - osteomalacia). It has also been proven by scientific statistics that lasers are beneficial in raising the pain threshold during and after surgery, as it reduces bleeding and treats various lesions, and even changes genetic material. Lasers can provide scientists with information about vital processes that take place inside cells, as the biological information provided by such studies can have important medical applications.

The most important medical uses of lasers are:

1. Skin diseases
2. Eye diseases
3. Nose and ear
4. Urinary tract.
5. Gynecology and obstetrics.
6. Dentistry
7. Cosmetic treatment.
8. Laser and human psychological state.
9. Laser rays to eliminate viruses in the blood.
10. Optical microscope.
11. Use of laser rays in immediate detection of tissue biopsies.
12. General surgery[5]

Helium-neon laser Basic components of helium-neon laser Advantages and disadvantages:

This laser is one of the most important types of gas lasers commonly used and is the first gas laser that operated with a continuous wave CW and a wavelength of 1.15 mμ in 1960. This system has three laser transitions with wavelengths (3.39 mμ, 1.15 mμ, 633nm). The helium: neon laser consists of a mixture of helium atoms He and neon gas Ne in a certain ratio and the laser emission lines are due to the neon atom. The role of the helium atoms is to contribute to the pumping process and achieve the reverse qualification of energy levels related to the neon system. From the energy diagram of the levels for the laser transitions of both helium and neon atoms, it is clear that the energy levels 3S, 2S respectively for the neon atom are, as well as the energy levels 23S & 21S for the helium atom are semi-stable. These specifications support the process of effective excitation of the neon levels 3S, 2S by the method of resonant energy transfer, as it has been proven that this process represents the basic means of achieving reverse qualification in the helium neon laser. It is also possible for neon atoms to be excited directly to the desired level by colliding with the electrons resulting from the electrical discharge, but the process of reverse qualification of the levels 2S, 3S for the neon atom is carried out effectively and efficiently by the excited helium atoms. Thus, the stimulated emission of neon atoms occurs between the 3S levels and the 3P levels and between the 2S levels and the 2P levels, the transition from 3S2 to 3P4 with a wavelength of 3.39 mμ and the transition from 2S2 to 2P¬4 with a wavelength of 0.633 mμ (red) and the transition from 2S2 to 2P¬4 with a wavelength of 1.15 mμ.

Then these atoms descend to the ground level quickly and automatically, and this may happen as a result of their collision with the walls of the tube containing the gas. Between the 2S levels and the

2P levels, the transition from 3S2 to 3P4 is at a wavelength of 3.39 mμ, the transition from 2S2 to 2P¬4 is at a wavelength of 0.633 mμ (red color), and the transition from 2S2 to 2P¬4 is at a wavelength of 1.15 mμ. Then these atoms descend to the ground level quickly and automatically, and this may happen as a result of their collision with the walls of the tube containing the gas. As for whether the helium-neon laser will oscillate in this transition or that, this depends on the selection of the resonator mirrors, and for oscillation at a specific wavelength, the coating of the two mirrors is used so that the maximum reflective power is at the required wavelength. The ratio of helium gas to neon gas for the transition of 0.633 Am is 1:5. The output power of visible light radiation from a cylindrical discharge tube with a length of one meter and a diameter of 6 mm is about 0.1 Watt. Most laboratory helium-neon laser tubes are (1-6) mm in diameter and (2015) cm in length, so the output power does not exceed one milliwatt. In addition to the uses of the helium-neon laser that oscillates in the visible red transition in educational laboratories, it is used for purposes that require a straight visible light beam with low power for use in alignment purposes or reading codes or in video disc memory. Similar to the use of the rare gas neon atom to generate laser rays, the rest of the rare gases such as krypton, argon and xenon have also been used in the same way, as the energy diagram for all of them is almost similar, and this is similar to neon.

Principle of Operation:

On the basic principle of Hene radiation emission, the stimulated laser works. This process involves two basic steps: injecting energy into the system and then releasing that energy in a coherent light beam. The energy is initially supplied to a mixture of helium and neon gases in the form of an electrical discharge, which excites the helium atoms.

1. The excited helium atoms collide with the neon atoms, transferring their energy.
2. The neon atoms, now in an excited state, emit photons when they return to their ground state.
3. These photons stimulate other excited neon atoms to emit more photons of the same wavelength, direction and phase, resulting in a coherent light beam - the laser beam.

A typical HeNe laser consists of several basic components:

Laser tube: It is a sealed glass tube containing a mixture of helium and neon gases, usually in a ratio of about 10:1 of helium to neon.

Electrodes: They are placed at both ends of the laser tube and provide the electrical discharge necessary to excite the helium atoms.

Optical resonator: It consists of a pair of mirrors placed at both ends of the tube, and the optical resonator directs and amplifies the laser beam. One of the mirrors is fully reflective, while the other is partially reflective to allow the laser beam to exit.

Key features of the HeNe laser:

HeNe lasers are known for their excellent beam quality and very low divergence, making them ideal for interferometry, holography, and scanning the most common red beam at a wavelength of Hee barcodes. The laser emits at 632.8 nm, but can also be designed to emit at other wavelengths, ranging from infrared to green regions of the light spectrum. Furthermore, the HeNe laser is known for its long coherence length and stable output power, which are essential for many experimental and industrial applications. Despite the advent of newer laser technologies, the HeNe laser remains a reliable and invaluable tool in the world of photonics.

Advantages and Disadvantages:

The HeNe laser has strengths and weaknesses:

The HeNe laser offers several advantages and benefits, including excellent beam quality, low beam divergence, long coherence length, and stable output power. In addition, its simple design and robustness contribute to its long life and low maintenance requirements.

On the negative side of the laser (HeNe) are disadvantages and weaknesses:

Helium is ineffective as an inert gas in some medical applications, such as MRI, neon is ineffective as an inert gas in some medical applications, such as radiotherapy, neon is a rare element, which makes it expensive to use in medical applications

Use of helium neon in medicine:

1. Ophthalmology
2. Doppler velocity meter
3. Treatment of stomach ulcers
4. Genetic engineering

Laser in the treatment of glaucoma:

There is an internal gland in the eye to secrete a special fluid to nourish the internal tissues of the eye, and when it performs its function, it exits through channels to the outside, so if these channels are blocked, an increase in eye pressure occurs, which leads to atrophy of the optic nerve, which causes loss of vision.

The treatment of glaucoma (glaucoma) by surgery is known in ancient times, but the modern use is to use a laser to create an opening to drain the fluid instead of the blocked channels, and argon, yag and helium-neon lasers have been used successfully in performing such operations.]5]

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