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A Review On The He-Ne Laser System

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Abstract: The first continuous-wave (CW) laser to be created was the He-Ne laser. Ali Javan and his colleagues W. R. Bennet and D. R. Herriott revealed the production of a cw He-Ne laser a few months after Maiman declared his invention of the pulsed ruby laser. Neon atoms are excited by helium atoms in this four-level gas laser. The laser light is produced by the neon's atomic changes. Red light with a wavelength of 632.8 nm is produced by these lasers' most popular neon transition. In addition to producing various UV and IR wavelengths, these lasers may also produce green and yellow light in the visible spectrum (Javan's first He-Ne operated in the IR at 1152.3 nm). It is feasible to make a given He-Ne's output work at a single wavelength by utilizing highly reflecting mirrors that are intended for one of these numerous possible lasing transitions.He-Ne lasers normally produce a few to tens of mW (milli-Watt, or 10^{-3} W) of power; they are not generators of high-power laser light. These lasers' extreme stability, both in terms of output light intensity (minimal jitter in power level) and wavelength (mode stability), is likely one of its most notable characteristics. He-Ne lasers are frequently used to steady other lasers for these reasons. They are also utilized in applications, like as holography, where mode stability is vital. He-Ne lasers dominated the market until the mid-1990s when they were manufactured for low-power uses, such as range finding, scanning, optical transmission, laser pointers, etc. However, due to lower costs, other types of lasers most notably semiconductor lasers seem to have emerged victorious in the recent rivalry. [30]

Keywords: He-Ne Laser, Energy Source, Gain Medium, Absorption, Spontaneous emission, Stimulated emission.

I. INTRODUCTION

A laser is a device that uses optical amplification, which is based on the stimulated emission of electromagnetic radiation, to emit light. Originally intended to stand for light amplification by stimulated emission of radiation, the name laser is an anacronym.[1][2] Theodore Maiman at Hughes Research Laboratories constructed the first laser in 1960 based on theoretical research by Charles H. Townes and Arthur Leonard Schawlow.[3] Coherent light is emitted by lasers, setting them apart from other light sources. Applications such as laser cutting and lithography are made possible by spatial coherence, which enables a laser to be focused to a small area. Additionally, it enables collimation, which keeps a laser beam narrow over long distances and is useful in lidar (light detection and ranging) and laser pointer applications. A highly narrow frequency spectrum can be emitted by lasers due to their excellent temporal coherence. As an alternative, temporal coherence can be utilized to create ultrashort light pulses of femtosecond durations that have a broad spectrum.

Lasers find application in cutting and welding materials, laser disc drives, laser printers, barcode scanners, DNA sequencing instruments, fiber-optic and free-space optical communication, semiconducting chip manufacturing (photolithography), laser surgery and skin treatments, and cutting and welding supplies. They are also used in laser lighting displays for entertainment purposes and in military and law enforcement devices for marking targets and measuring speed and range. In order to excite fluorescence as a white light source, semiconductor lasers operating in the blue to near-UV range have also been used in place of light-emitting diodes (LEDs). This allows for a much smaller emitting area because of the laser's much greater radiance and eliminates the droop that LEDs experience. Some automobile headlamps already use such devices.[4][5][6][7] The term "microwave amplification by stimulated emission of radiation" (maser) refers to the first device that used amplification by stimulated emission, and it worked at microwave frequencies.[8] Initially called optical masers, these identical optical devices were later abbreviated as lasers after the word "light" was substituted for the word "microwave" in the acronym.[9] These days, all of these devices—such as infrared, ultraviolet, X-ray, and gamma-ray lasers that operate at frequencies higher than microwaves at about 300 GHz and beyond are referred to as lasers, while those that operate at microwave or lower radio frequencies are referred to as masers.[10][11] In the field, to lase is a back-formed verb that means to give off coherent light, notably when referring to a laser's gain medium. [12] A laser is said to be "lasing" when it is in operation.[13] Naturally occurring coherent emissions are also referred to as masers or lasers, as in atom laser and astrophysical maser.[14][15] Despite what the term suggests, a laser that generates light on its own is actually an optical oscillator rather than an optical amplifier.

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[16] One funny observation is that it would have been more accurate to refer to the phenomenon as light oscillation by stimulated emission of radiation abbreviated LASER.[15] Due to the original acronym's extensive usage as a common noun, optical amplifiers are now also known as laser amplifiers.[17]

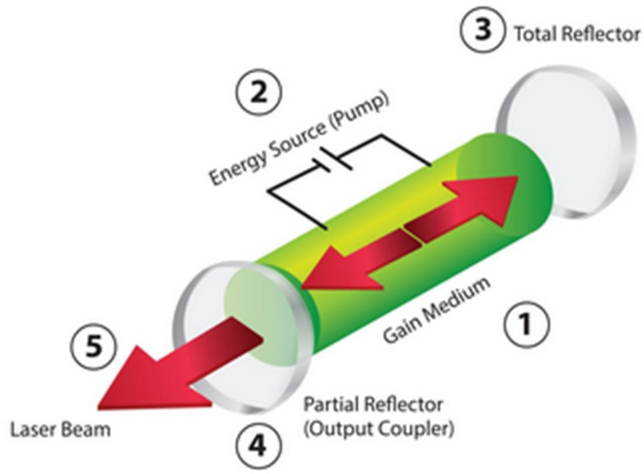


Figure 1: The components of a typical laser system [18]

II. LITERATURE REVIEW

Albert Einstein proposed in 1916 that, in the right conditions, atoms may spontaneously release excess energy as light or when stimulated by light. This idea eventually led to the development of the laser. In 1928, German physicist Rudolf Walther Ladenburg made the first observation of stimulated emission, however it didn't seem to have any applications at the time. [21] In 1951, while attending Columbia University in New York City, Charles H. Townes devised a method for producing stimulated emission at microwave frequencies. He showed off a functional apparatus that concentrated "excited" ammonia molecules in a resonant microwave cavity, causing them to emit a pure microwave frequency, at the end of 1953. For "microwave amplification by the stimulated emission of radiation," Townes gave the gadget the name maser. The theory of maser operation was separately described by two scientists from the P.N. Lebedev Physical Institute in Moscow: Nikolay Gennadiyevich Basov and Alexander Mikhaylovich Prokhorov. All three received a share of the 1964 Nobel Prize in Physics for their contributions. [21]

The mid-1950s saw a sharp increase in maser research, but atomic clocks and low-noise microwave amplifiers were the sole uses for masers. In 1957, Townes suggested that they attempt to expand the use of maser action to the considerably shorter wavelengths of visible or infrared light to his brother-in-law, Arthur L. Schawlow, a former postdoctoral student at Columbia University who was working at Bell Laboratories. Townes also spoke with Gordon Gould, a Columbia University graduate student who immediately came up with his own laser concepts. In a groundbreaking study published in the Physical Review on December 15, 1958, Townes and Schawlow presented their concepts for a "optical maser." In the interim, Gould produced a patent application and created the word "laser." The question of who should be acknowledged as the "inventor" of the laser Townes or Gould became very contentious and resulted in years of legal disputes. In the end, Gould was awarded four patents beginning in 1977, which brought in millions of dollars in royalties. [21]

The Townes-Schawlow proposal inspired other groups to attempt laser construction. The secret military contract was based on the Gould proposal. Theodore H. Maiman was the first to succeed at Hughes Research Laboratories in Malibu, California, by using an alternative strategy. He used a photographer's flash lamp to produce intense pulses that excited the chromium atoms within a synthetic ruby crystal. He selected this material after carefully examining its light-absorbing and light-emitting properties and determining that it should function as a laser. He created red pulses with a ruby rod the size of a fingertip on May 16, 1960. The first gas laser was created at Bell Labs in December 1960 by Ali Javan, William Bennett, Jr., and Donald Herriott. It used a helium and neon mixture to continuously produce an infrared beam. The first semiconductor laser was created in 1962 by Robert N. Hall and colleagues at the General Electric Research and Development Center in Schenectady, New York.[21]

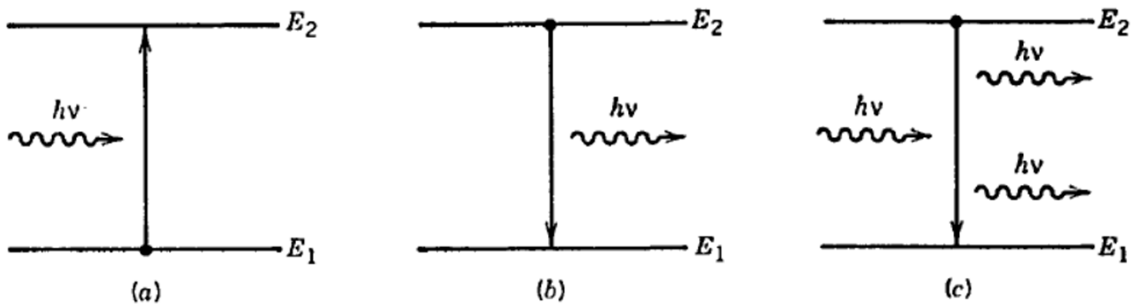
Though practical uses took years to develop, lasers soon captured the public's attention, partly because of their resemblance to the "heat rays" of science fiction. While working with Maiman on the ruby laser, a young physicist by the name of Irnee D'Haenens made a long-lasting joke in the laser community when she said that the device was "a solution looking for a problem.

" Townes and Schawlow had anticipated using laser beams for airborne or spaceborne signal transmission as well as basic research. Gould imagined more potent beams that could drill and cut through a variety of materials. A significant early achievement occurred in late 1963 when Emmett Leith and Juris Upatnieks, two researchers at the University of Michigan, created the first three-dimensional holograms using lasers.[21]

The first widely used lasers in commerce were helium-neon lasers. Straight lines could be projected for alignment, surveying, construction, and irrigation right away since they could be set to produce a visible red beam rather than an infrared one. Ruby laser pulses were soon being used by eye surgeons to fuse detached retinas back together without making incisions in the eye. The laser scanner used for automated checkout in supermarkets was the first widespread use of lasers; it was created in the middle of the 1970s and gained popularity a few years later. Personal computer laser printers and compact disc music players quickly followed.[21] Lasers are becoming commonplace instruments in many fields. In lecture halls, laser pointers draw attention to presentation points, and laser target designators direct smart bombs to their intended targets. Razor blades are welded, undesired hair is removed, tattoos are bleached, and patterns are written on manufacturing line products without ever touching them using lasers. The surfaces of Mars and the asteroid Eros were profiled in unprecedented detail by laser rangefinders aboard space spacecraft. Physicists have used lasers in the lab to chill atoms to within a very small degree of absolute zero.[21]

III. THE PRINCIPLE OF LASER OPERATION

The laws of quantum physics, which restrict atoms and molecules to possessing finite amounts of stored energy that vary depending on the nature of the atom or molecule, shape laser emission. When all of an atom's electrons are in the closest orbits to its nucleus, the atom has the lowest energy attainable (see electronic configuration). We refer to this stage as the ground state. An atom is said to be "excited" when one or more of its electrons have taken in energy and are able to travel to outer orbits. In general, excited states are unstable because light is released as electrons transition from higher to lower energy levels.[21]



(a) Absorption (b) Spontaneous emission and (c) stimulated emission

Figure 2: The three fundamental processes occurring between the two energy states of an atom [19]

Einstein realized there were two possible ways to produce this emission. Discrete light packets, or photons, are typically released spontaneously and without the help of an external source. Alternatively, if the energy of the passing photon precisely matched the energy that an electron would release spontaneously upon descending to a lower-energy configuration, it may cause an atom or molecule to emit light. The proportion of lower-energy to higher-energy combinations determines whether process is dominant. Lower-energy setups are typically more common. Accordingly, it is more likely for a photon that spontaneously emits to be absorbed and raise an electron from a lower-energy configuration to a higher-energy configuration than it is for a second photon to be released in order to cause a higher-energy configuration to descend to a lower-energy configuration. Stimulated emission will cease as long as lower-energy states are more prevalent.[21] Nonetheless, spontaneously released photons are more likely to trigger more emissions, creating a cascade of photons, if higher-energy configurations predominate (a situation referred to as population inversion). A population inversion cannot be produced by heat alone; an additional technique is needed to specifically excite the atoms or molecules. This is usually accomplished by either shining a strong light on the laser material or by running an electric current through it.[21]

There are just two energy levels in the most basic system that can be imagined, like Townes' ammonia maser. Three or four energy levels are involved in more practical laser systems. The material in a three-level laser is initially stimulated to a high-energy, brief state that then spontaneously transitions to a relatively lower-energy state known as a metastable state, which has an exceptionally long lifespan.

The reason the metastable state matters is that it retains and traps excitation energy, causing a population inversion that can be further induced to release radiation and return the species to its ground state. A three-level laser is the ruby laser created by Theodore Maiman.[21] Unfortunately, the three-level laser can only function in the event that the ground state is empty. Most three-level lasers are limited to producing pulses because when atoms or molecules produce light, they build up in the ground state, where they can absorb the stimulated emission and stop the laser action. The four-level laser solves this problem by having an additional transition state situated between the ground and metastable levels. As a result, numerous four-level lasers can provide a continuous beam for several days.[21]

IV. THE ELEMENTS AND CHARACTERISTICS OF LASER BEAM

Although population inversions can occur in liquids or solids, gasses and solids make up the majority of laser media. Usually, an electric current or external light source is used to excite laser gasses inside the cylindrical tubes, a process known as "pumping" the laser. Likewise, transparent crystals or semiconductors with trace amounts of light-emitting atoms can be used in solid-state lasers.[21] To increase the amount of light energy in the beam, an optical resonator is required. A pair of mirrors placed facing each other such that light emitted along the line between the mirrors is reflected back and forth creates the resonator. Light that is reflected back and forth across the laser medium becomes more intense with each pass when a population inversion occurs in the medium. Unamplified light seeps in from the mirrors' surroundings. Only a portion of the incident light is transmitted by one or both mirrors in a real laser cavity.[0] The type of laser determines the fraction of light transmitted, or the laser beam. The amount of light added by stimulated emission on each round trip between the mirrors, if the laser produces a continuous beam, equals the light appearing in the beam plus losses within the optical resonator.[21]

Technically , a laser oscillator is created when a resonant cavity and laser medium are combined to create what is often referred to as a laser. Many laser characteristics are determined by oscillation, which indicates internal light generation in the apparatus. A laser would be nothing more than an optical amplifier in the absence of mirrors and a resonant cavity; it could only amplify light coming from an external source and not produce an internal beam. The first optical amplifier was demonstrated in 1961 by American Optical researcher Elias Snitzer, but applications for these devices were limited until the rise of fiber optic-based communications.[21]

Generally , laser light is distinct from other types of light because it is concentrated into a narrow beam, restricted to a small range of wavelengths (commonly referred to as "monochromatic"), and composed of waves that are phase-locked to one another. These characteristics result from interactions between the laser medium, the resonant cavity, and the stimulated emission process.[21]A photon that is stimulated will produce another photon that is identical to the original, with the same phase, wavelength, and direction. As a result, the two photons are coherent, with phase peaks and valleys, with respect to one another. Then, other identical photons can be stimulated to emit by both the original and the new photon. This uniformity is increased by alternating the light through a resonant cavity; the laser design determines the beam's narrowness and coherence. Even if a visible laser appears to be pointing at a location on the wall across from you in a room, the beam's collimation is not always perfect. The distance between the laser mirrors and diffraction, which scatters light at an aperture's edge, determine how much the beam spreads. The amount of diffraction is directly related to the laser wavelength divided by the emitting aperture size; the beam spreads more slowly through larger apertures.[21]

At a wavelength of 0.633 micrometers, a red helium-neon laser emits light from a one-millimeter aperture. The resulting beam diverges at an angle of around 0.057 degree, or one milliradian. At a distance of one kilometer, a one-meter spot will result from such a modest angle of divergence. On the other hand, a standard flashlight beam creates a comparable one-meter spot in a matter of meters. Still, not every laser produces a tight beam. Semiconductor lasers require external optics to concentrate their beams since they emit light with a wavelength of close to one micrometer from an aperture of similar size, meaning that their divergence is at least 20 degrees.The laser material, the stimulated emission process, and the laser resonator's optics all affect the output wavelength. A material can support stimulated emission throughout a specific range of wavelengths for each energy level transition; the range's extent depends on the nature of the material and the transition. The mechanism concentrates emission at wavelengths where the chance of stimulated emission is largest. The probability of stimulated emission changes with wavelength.[21]

Laser oscillation is supported by resonant cavities at wavelengths that satisfy a resonant requirement, which is that the integral number N of wavelengths λ must match the round trip distance of light between the mirrors. The round-trip distance 2L must equal $N\lambda/n$, or $2L = N\lambda/n$, if the cavity length is L and the material's refractive index is n in the laser cavity. We refer to each resonance as a longitudinal mode. The wavelengths of neighboring modes are closely separated, with the exception of semiconductor lasers, and the laser often generates light concurrently on two or more wavelengths that are within 0.1 percent of one another.

For most practical purposes, these beams are monochromatic; additional optics can be added to restrict laser oscillation to an even narrower wavelength range and to a single longitudinal mode.[21] A beam is more coherent when its wavelength range is less, indicating that all of the light waves inside it are exactly synchronized with each other. The coherence length is a metric used to measure this. This coherence length = $\lambda 2/2\Delta\lambda$ if the center of the wavelength range that is emitted is λ and the wavelength range that is emitted is $\Delta\lambda$. Coherence lengths typically vary from millimeters to meters. For example, recording three-dimensional object holograms requires such lengthy coherence durations.

The typical power of a laser can range from microwatts to over a million watts in the case of the most powerful experimental lasers. Lasers can produce pulsed or continuous beams. When a laser produces an output that is essentially constant over a period of seconds or more, it is referred to be continuous-wave; the steady red beam produced by a laser pointer is one example. The output energy of pulsed lasers is concentrated into short, high-power bursts. One or more pulses can be fired by these lasers at regular intervals. At the peak of an incredibly brief pulse, instantaneous power might be very high. Peak power output from laboratory lasers has surpassed 10^{15} watts for durations of roughly 10^{-12} seconds.[21] In laboratory investigations, pulses can be compressed to a very short period of approximately 5 femtoseconds (5×10^{-15} seconds) to freeze the activity during incredibly rapid occurrences, including steps in chemical processes. Similar to how a magnifier concentrates sunlight onto a small spot to ignite paper, laser pulses may likewise be focused to concentrate high strengths on small spots.[21]

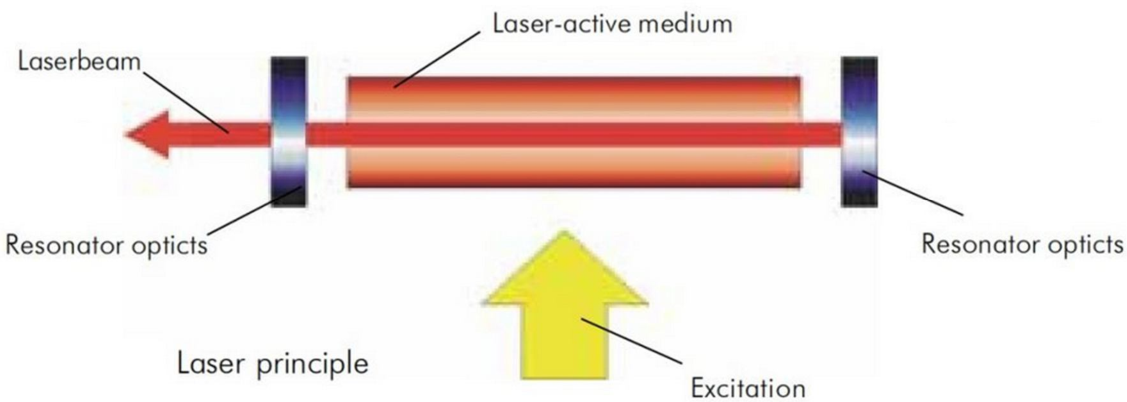


Figure 3: The basic principle of laser physics [20]

V. HELIUM-NEON LASER

A helium-neon laser, also known as a He-Ne laser, is a kind of gas laser with a high energy medium gain medium made up of a mixture of helium and neon at a pressure of roughly 1 Torr (133 Pa) total inside a tiny electrical discharge. The ratio of helium to neon can range from 5:1 to 20:1. In the visible spectrum's red region, at a wavelength of 632.8 nm in air, is where the most well-known and often used He-Ne laser operates. [22] The original He-Ne lasers were gas lasers with continuous wave output that let off infrared light at 1150 nm. But a visible-wavelength laser was considerably more in demand, thus several additional neon transitions were studied to find ones where a population inversion can be accomplished. Since the 633 nm line has the maximum gain in the visible spectrum, most He-Ne lasers operate at this wavelength. He-Ne lasers could be designed to use transitions such as visible lasers appearing red, orange, yellow, and green by using mirror coatings with their peak reflectance at these other wavelengths. Other visible and infrared stimulated-emission wavelengths are also feasible.[23] From over 100 μm in the far infrared to 540 nm in the visible, stimulated emissions are known. These lasers are usually more expensive and have poorer output efficiency because to visible transitions' slightly lower gain. The transition at 3.39 μm has an extremely high gain, but the cavities and mirrors are lossy at that wavelength, therefore it cannot be used in a regular He-Ne laser (of a different intended wavelength). However, superluminescence at 3.39 μm can become a nuisance in high-power He-Ne lasers with a particularly long cavity, stealing power from the stimulated emission medium and frequently needing further suppression.The most popular and extensively utilized He-Ne laser functions at a wavelength of 632.8 nm, which falls inside the visible spectrum's red region. It was created at Bell Telephone Laboratories in 1962,[23][24] eighteen months after the first continuous infrared He-Ne gas laser was shown there in December 1960.[25]

As implied by the name, the laser's gain medium is a combination of helium and neon gases, around 10:1, held at low pressure in a glass envelope. In order to excite helium atoms, the majority of the gas mixture is composed of helium.

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The excited helium atoms collision with neon atoms, exciting some of them to the state that radiates 632.8 nm. Non-laser lines would result from the neon atoms being predominantly excited to lower excited states in the absence of helium. Although it is possible to build a neon laser without helium, it is far more challenging without this kind of energy coupling. Because of the excessively poor pumping efficiency, a He-Ne laser that has lost sufficient helium will no longer function as a laser.[26] An electrical discharge with a high voltage that travels through the gas between the anode and cathode electrodes in the tube provides the laser's energy or pump source. Generally, CW functioning requires a DC current of 3 to 20 mA. Two concave mirrors, or one plane and one concave mirror, make up the laser's optical cavity. The output coupler mirror allows for about 1% of transmission, while the other mirror has an extremely high reflectance of 99.9%. Comparatively speaking to other gas lasers, commercial He-Ne lasers are smaller devices. Their optical output power levels range from 0.5 to 50 mW, and their cavity lengths typically range from 15 to 50 cm (but occasionally they can reach up to roughly 1 meter to obtain the maximum powers). Red He-Ne lasers have an exact wavelength of 632.991 nm in a vacuum, which is refracted to roughly 632.816 nm in air. The stimulated emission modes' wavelengths move within this range as a result of the cavity's thermal expansion and contraction, and they fall between 0.001 nm and this value. With frequency-stabilized versions, the powers of two longitudinal modes in opposite polarizations can be compared to determine the wavelength of a single mode to within 1 part in 10^8.[27] An iodine absorption cell can be used to achieve absolute stability of the laser's frequency or wavelength as fine as 2.5 parts in 10^{11}.[28]

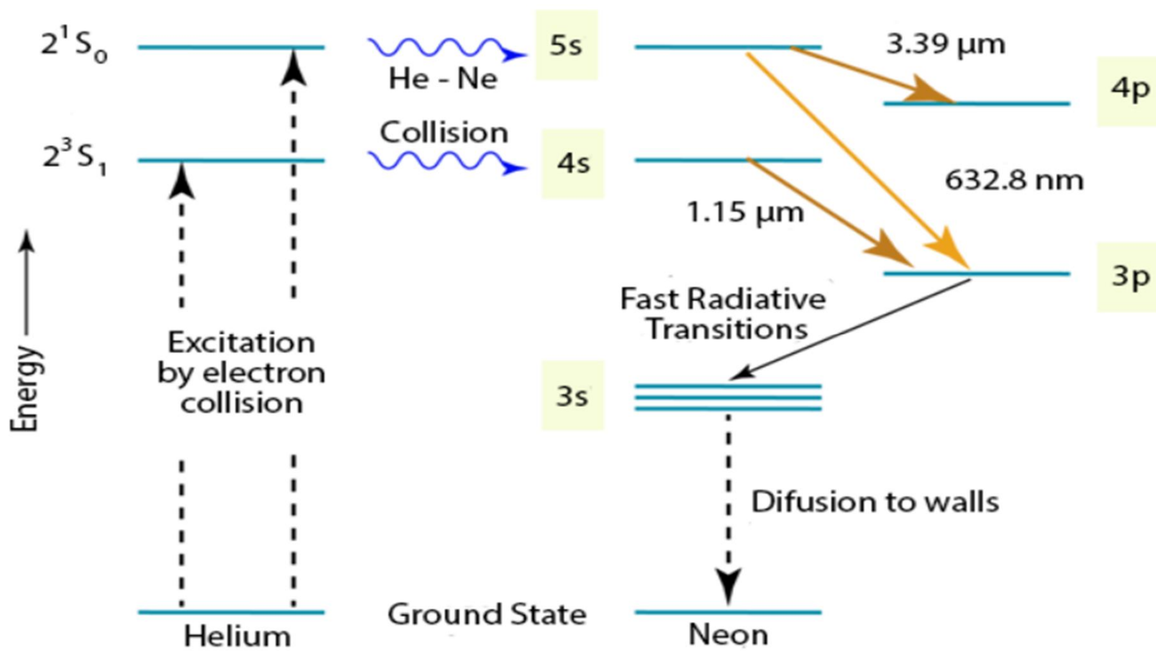


Figure 4: Energy levels in a He-Ne Laser [29]

Gas lasers known as helium-neon lasers use a combination of helium and neon gases at a pressure of roughly one torr as its gain medium. They produce an output wavelength of 632.8 nm, which is in the electromagnetic spectrum's infrared region. However, by employing mirror coatings that reflect at these wavelengths, it is feasible to produce emissions at various wavelengths, from 100 µm in the far infrared region to 540 nm in the visible region. The He-Ne laser is a continuous wave laser with a lifetime of up to 50,000 hours. Its normal length is 0.15 to 0.5 m. This laser can produce optical powers between 0.5 and 50 mW.[29]

Electric discharge, in which highly excited electrons collide with the gas mixture in the active medium, is the method used to pump He-Ne lasers. There is an energy transfer from the pump electrons to the mixture of helium and neon gases because these collisions are inelastic. He gas functions as a buffer gas, giving the Ne atoms enough energy to create laser output, while the neon gas's atomic transitions cause photon emission in a He-Ne laser because they have energy levels appropriate for the laser transition.[29] The majority of the energy provided by the electrodes within the laser cavity is absorbed by the He atoms that make up the He-Ne gas mixture through electric discharge.Energy is transferred to the He atoms as a result of the collision between the energetic electrons created by electric discharge and the He atoms. The He atoms are excited to higher metastable energy levels indicated by 2^3S_1 and 2^1S_0 by this inelastic collision.

The excited atoms in the metastable states of He atoms are long-lived energy levels, therefore they are unable to spontaneously emit back to the ground state. Because the excited energy levels (4s and 5s) of Ne atoms are identical to the metastable energy levels of He atoms, the He atoms transfer their energy to the Ne atoms by collision.[29]

The entire transfer of energy from the He atoms to the Ne atoms occurs at the collision between the two atoms. Consequently, the He atoms lose energy and return to the ground state, while the Ne atoms are excited to the upper energy levels 4s and 5s, which are metastable states. Due to the long lifetime of the metastable states of Ne atoms, population inversion between the energy levels of Ne atoms develops as a result of this process. He atoms thus aid in the population inversion of Ne atoms.[29] Through induced emission of laser radiations at 1.15 µm (corresponding to the 4s to 3p transition), 3.39 µm (corresponding to the 5s to 4p transition), and 632.8 nm (corresponding to the 5s to 3p transition), the electrons in the higher laser level of Ne atoms return to lower energy levels. Among these, 632.8 nm consistently dominates, with the production of other wavelengths contingent upon the application of appropriate cavity mirror coatings. Rapid radiative decay to the 3s state effectively emptys the 3p level before reaching the ground state.[29]

There are several uses for He-Ne lasers.It is employed in interferometry, where it offers the highly stable, single-transverse-mode reference beam required to determine the optical characteristics of materials, such as smoothness and surface figure.It is employed in laser printing, where the well-characterized beam is used as a writing source on photosensitive material to generate detailed print patterns.He-Ne lasers are used as inventory or check-out scanners by the majority of super markets and other retailers to read the digitally encoded bar codes on merchandise. Applications for pointing include target-aiming devices for firearms, three-dimensional right-angle reference beams used in the construction sector, reference beams for surveying, and reference beams for aligning sewer pipes.Measurements of optical fiber transmission lines, which have the least loss in that wavelength range, are done using the 1.523µm laser.[29]

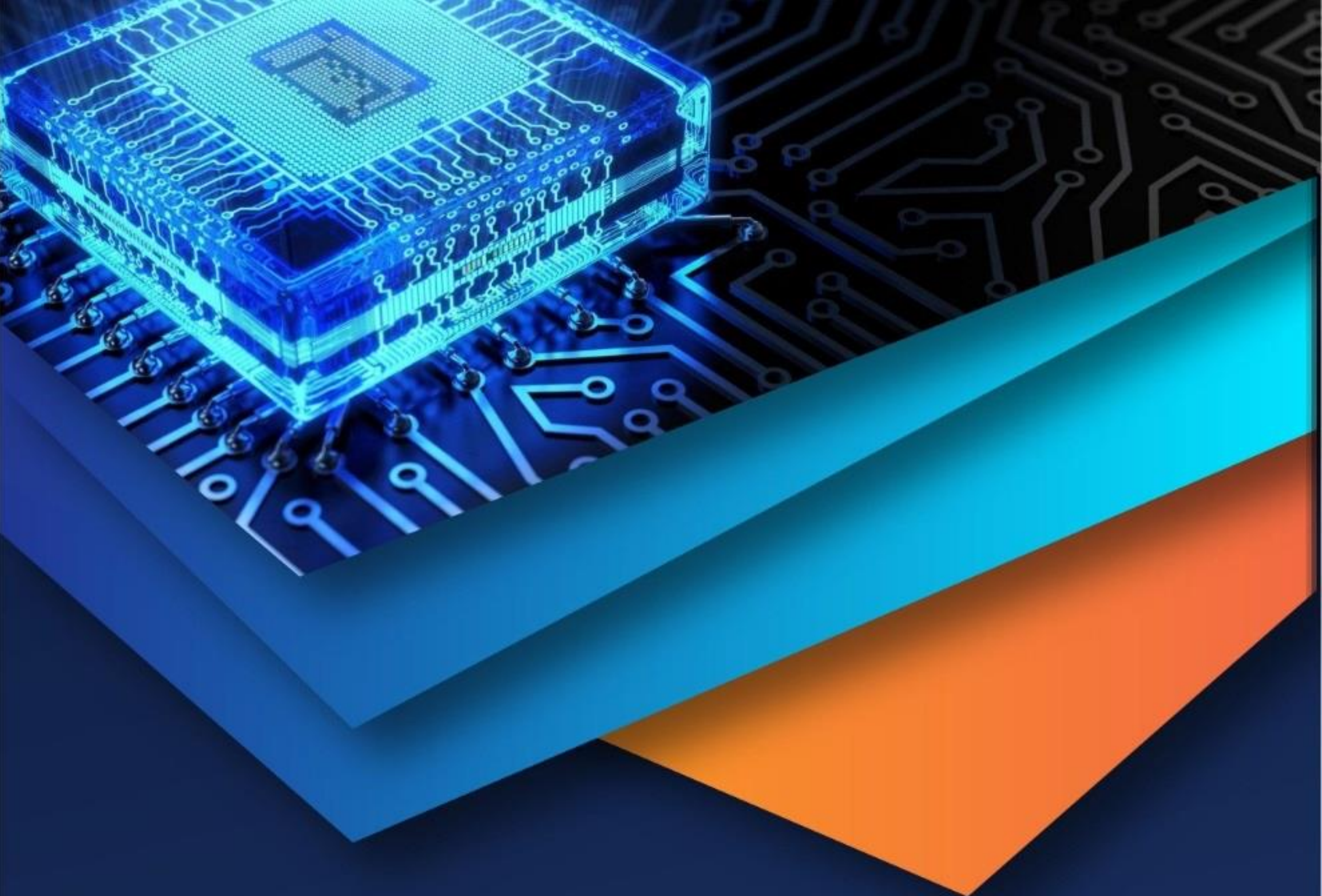
VI. CONCLUSION

Even with their many excellent intrinsic qualities, He-Ne lasers frequently fall short of what is needed in today's industrial settings. Because durability and longevity are essential for industrial production lines that operate around the clock, manufacturers of industrial instruments typically spend two to four times as much for lasers because they last longer and are simpler to replace and maintain.The number of semiconductor laser parameters that must be near to HeNe laser performance determines how much more expensive HeNe lasers are. Single-mode or polarization-maintaining fiber must be utilized, a good round beam shape, and diffraction-limited divergence if flawless beam quality is required. A semiconductor emitter with adequate temperature and power stabilization can have a reasonably good center wavelength stability. The long coherence length requirement is the most costly and challenging to meet. Employing volume Bragg gratings or fiber Bragg gratings in external cavity designs the ECDL - external cavity diode laser is the most common method of guaranteeing long coherence length and very stable (<5 pm) center wavelength.The truth is that it is difficult or prohibitively expensive to outperform the HeNe, but laser integrators are willing to make some pretty big-time compromises; as a result, we are seeing conventional HeNe laser manufacturers cease manufacturing. In numerous industrial applications, semiconductor lasers are effectively replacing HeNe lasers as more and more of them hit the market. It appears that HeNe lasers will not be used in Industry 4.0, but rather serve as a reference in some calibration applications in the future.[31]

REFERENCES

[1] Taylor, Nick (2000). Laser: The Inventor, The Nobel Laureate, and The Thirty-Year Patent War. Simon & Schuster. p. 66. ISBN 978-0684835150.
[2] Ross T., Adam; Becker G., Daniel (2001). Proceedings of Laser Surgery: Advanced Characterization, Therapeutics, and Systems. SPIE. p. 396. ISBN 978-0-8194-3922-2.
[3] "December 1958: Invention of the Laser". aps.org. Archived from the original on December 10, 2021. Retrieved January 27, 2022
[4] Semiconductor Sources: Laser plus phosphor emits white light without droop". November 7, 2013. Archived from the original on June 13, 2016. Retrieved February 4, 2019.
[5] Laser Lighting: White-light lasers challenge LEDs in directional lighting applications". February 22, 2017. Archived from the original on February 7, 2019. Retrieved February 4, 2019.
[6] How Laser-powered Headlights Work". November 7, 2011. Archived from the original on November 16, 2011. Retrieved February 4, 2019.
[7] Laser light for headlights: Latest trend in car lighting | OSRAM Automotive". Archived from the original on February 7, 2019. Retrieved February 4, 2019.
[8] Heilbron, John L. (March 27, 2003). The Oxford Companion to the History of Modern Science. Oxford University Press. pp. 447. ISBN 978-0-19-974376-6.
[9] Bertolotti, Mario (October 1, 2004). The History of the Laser. CRC Press. pp. 215, 218–219. ISBN 978-1-4200-3340-3.
[10] [McAulay, Alastair D. (May 31, 2011). Military Laser Technology for Defense: Technology for Revolutionizing 21st Century Warfare. John Wiley & Sons. p. 127. ISBN 978-0-470-25560-5.

[11] Renk, Karl F. (February 9, 2012). Basics of Laser Physics: For Students of Science and Engineering. Springer Science & Business Media. p. 4. ISBN 978-3-642-23565-8.
[12] LASE". Collins Dictionary. Retrieved January 6, 2024.
[13] "LASING". Collins Dictionary. Retrieved January 6, 2024.
[14] Strelnitski, Vladimir (1997). "Masers, Lasers and the Interstellar Medium". Astrophysics and Space Science. 252: 279–287. Bibcode:1997Ap&SS.252..279S. doi:10.1023/
[15] Chu, Steven; Townes, Charles (2003). "Arthur Schawlow". In Edward P. Lazear (ed.). Biographical Memoirs. Vol. 83. National Academy of Sciences. p. 202. ISBN 978-0-309-08699-8
[16] Al-Amri, Mohammad D.; El-Gomati, Mohamed; Zubairy, M. Suhail (December 12, 2016). Optics in Our Time. Springer. p. 76. ISBN 978-3-319-31903-2.
[17] Hecht, Jeff (December 27, 2018). Understanding Lasers: An Entry-Level Guide. John Wiley & Sons. p. 201. ISBN 978-1-119-31064-8.
[18] https://www.ulsinc.com/learn
[19] https://www.fiberoptics4sale.com/blogs/wave-optics/semiconductor-laser-physics
[20] https://www.szlaser.com/index.php/wiki/laser-physics/
[21] https://www.britannica.com/technology/laser
[22] https://en.wikipedia.org/wiki/Helium%E2%80%93neon_laser
[23] White, A.D.; Rigden, J.D. (1962). "Correspondence: Continuous gas maser operation in the visible". Proceedings of the IRE. 50 (7). Institute of Electrical and Electronics Engineers (IEEE): 1697. doi:10.1109/jrproc.1962.288157. ISSN 0096-8390
[24] White, A.D. (October 2011). "Recollections of the first continuous visible laser". Optics and Photonics News. Vol. 22, no. 10. pp. 34–39.
[25] Javan, A.; Bennett, W.R.; Herriott, D.R. (1 February 1961). "Population inversion and continuous optical maser oscillation in a gas discharge containing a He–Ne mixture". Physical Review Letters. 6 (3). American Physical Society (APS): 106–110.
[26] "Sam's Laser FAQ – Helium-Ne Lasers". K3PGP.org.
[27] Niebauer, T.M.; Faller, James E.; Godwin, H.M.; Hall, John L.; Barger, R.L. (1988-04-01). "Frequency stability measurements on polarization-stabilized He–Ne lasers". Applied Optics. 27 (7). The Optical Society: 1285–1289. Bibcode:1988ApOpt..27.1285N. doi:10.1364/ao.27.001285. ISSN 0003-6935. PMID 20531556
[28] Iodine-stabilized helium–neon laser. National Institute of Standards and Technology (NIST). NIST Museum (Report). U.S. Department of Commerce. Archived from the original on 21 July 2006.
[29] https://www.gophotonics.com/community/what-are-he-ne-lasers.
[30] https://chem.libretexts.org/Bookshelves/Physical_and_Theoretical_Chemistry_Textbook_Maps/Physical_Chemistry_(LibreTexts)/15%3A_Lasers_Laser_Spectroscopy_and_Photochemistry/15.06%3A_The_Helium-Neon_Laser
[31] https://integratedoptics.com/hene-lasers



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