International Journal of Scientific & Engineering Research, Volume 5, Issue 10, October-2014
ISSN 2229-5518

Medical Application of Output Intensity Characterization of Red He-Ne Laser

*Farman Ali Mangi, **Bayor Jude Simons, *Deedar Ali Jamro, ***Noor Ahmed Shaikh, ***Ghullam Ali Mallah

Abstract—The object of this paper is to obtain the output intensity of He-Ne laser by investigating the specific novel characteristics of calculated parameters of the laser for medical application. Low-level He-Ne laser is commonly used in therapy and has advantages of having beneficial effects on tissue healing and pain relief. However, present studies show that the effectiveness of this modality varies. Hence, this research focuses on computing the characterization of the output intensity at variant ratios of Helium and Neon mixture of laser with different wavelengths and pressures for standard effective medical therapy. Using mirror coatings with their peak reflectance at these wavelengths and pressures, the intensity measurements of He-Ne laser were carried out. It concludes that based on certain standardized wavelengths and associated pressures, the intensity of variant ratio of He-Ne lasers output are achievable

Index Terms— Intensity, Helium Neon LASER, Glass Envelope, Estimation, Capillary Tube, Population Inversion, Photomultiplier Tube, Monochromator

1 INTRODUCTION

LASER is a device that create a uniform and coherent beam of light based on stimulated emission of electromagnetic radiation. Many types of LASERs are used in medical application such as cauterizing tissues, corrective eyes surgery and providing a source of heat for cutting. Nevertheless, there are various application of He-Ne LASER in medical field; for instance, Blood cell analysis (cytometry), for the diagnostic and treatment of the patients and skin wound healing. The Helium Neon LASER is a type of small gas LASER with the typical operational wavelength of 632.8 nm in the red part of the visible spectrum. It consists of a mixture of Helium and Neon gases with an approximate ratio of 10:1, which is contained at low pressure (typically ~300 Pa) in a glass envelope. The energy or pump source of the laser is provided by an electrical discharge of around 1000 V through an anode and cathode arrangement at each end of the glass tube. The optical cavity of the LASER is typically composed of the two mirrors; one being a high reflectance mirror while the other is an output coupler mirror.

In this arrangement one of the mirrors reflects virtually 100% of the desired wavelength and while the other about 99% so that also has a high reflectance but allows 1% of the light to pass through the mirror. The fluctuations of exciting source in order to He-Ne laser in DC, the uniform distribution of plasma density and moving striations have certain effects on characteristics of laser [1].

- ***Farman Ali Mangi*** *is currently pursuing PhD degree in the field of Physical Electronics, University of Electronics Science & Technology, Chengdu, Sichuan, China. PH-008615002836807. E-mail: farmanali29@yahoo.com*
- ***Bayor Jude Simons*** *is currently pursuing PhD degree in the field of Plasma Physics, School of Physical Electronics, University of Electronics Science & Technology, Chengdu, Sichuan, China. PH- 008615928449450. E-mail: bayorjude@yahoo.com* (Th*is information is optional; change it according to your need.)*
- ***Deedar Ali Jamro*** *is currently pursuing PhD degree in the field of Physical Electronics, University of Electronics Science & Technology, Chengdu, Sichuan, China. PH-008615708444009. E-mail: Deedar.jamro@salu.edu.pk*

Energetic electrons are accelerated from the cathode to the anode and in so doing collide with Helium and Neon atoms in the laser tube. This leads to a production of a large number of neutral Helium and Neon atoms which are in excited states. These He and Ne atoms in excited states then can de-excite and return to their ground states by spontaneously emitting light. This light accounts for the bright pink-red glow of the plasma that is seen even in the absence of laser action.

In principle, to achieve laser action it is necessary to have a large number of atoms in excited states and to establish population inversion. The population inversion of the neon atoms can be achieved by an electrical glow discharge which will create plasma with high energy electrons while not otherwise affecting the kinetic energy of the remaining atoms. The electrons then ionize the gas mixture which then excites the helium ions into a metastable state. An energy transfer between this metastable state and the neon atoms turns out to be very efficient and is therefore responsible for most of the neon's population inversion process, even though some of the population inversion to an extent, is facilitated by direct electron impact as well.

Excited Helium atoms in collision with Neon atoms render Neon atoms to be in an excited state and they emit radiation. For Helium-Neon LASERs, the Neon atoms are the source of LASER light. The emitted laser beam do have an intensity which can be measured. Intensity is the flow of energy per unit area per unit time and is proportional to the voltage. Gas temperature distribution determines characteristic constants for the heavy particle interaction, including asymmetric charge transfer, Penning ionization, and diffusion, as is demonstrated in [2] and [3]. The Gaussian form is described by the following equation

$$P(v) = \frac{1}{\sigma\sqrt{2\pi}}\left\{e^{-\frac{1}{2}\left(\frac{v-u}{\sigma}\right)^2}\right\} \qquad (1)$$

Where μ represents the replica mean, σ is the square root of the variance, which is also referred to as the standard deviation [4]. This form is advantageous because it allows us to see the probability of measuring certain intensities. In measuring the intensity, care must be taken to ensure that detector saturation is avoided. Here, detector saturation is explained to be when the detector operates at a level where the response is non-linear [5]. What was measured as intensity was actually the integrated intensity distribution. The integrated intensity distribution can be fitted to an error function:

$$\mathbf{erf}(y) = \frac{2}{\sqrt{\pi}} \left(\int_0^y e^{-x^2}\, dx \right) \qquad (2)$$

For this data to fit with the Gaussian form, its derivative has to be taken. The divergence of a laser beam is taken to where the beam no longer meets at a single point. Hence to determine this, linear regression was used. Linearly polarized light is light for which the orientation of the electric field is constant [6]. The average electron temperature is obtained by the measurement of the relative intensities of some He and Ne spectral lines [7]. Its intensity can be described by Malus' law.

$$I = I_0 \{(\mathrm{Cos}\ \theta)^2\} \qquad (3)$$

Where I_0 is the intensity of the incident polarized light, I is the intensity, and θ is the angle. The polarization of the laser can be described by this above equation [8]. Brewster's angle usually involves the reflected intensity and not the trans-mitted. The transmitted intensity is related to the reflected by the following equation

$$\mathbf{R + T = 1} \qquad (4)$$

Where R is the reflected light, and T is the transmitted light [9].

2. Intensity Application of He-Ne LASER

The intensity of Helium-Neon laser finds common utilization in the broad range of biomedical applications. Hence low intensity laser therapy is widely used for wound healing promotion and its mechanism of action may be attributed to an enhancement of blood supply. In general wound healing is a complex biological sequence of events in order to repair bodily damage. For the normal healing process, the approach essentially requires a thorough sequential procedure which results in the immediate filling of the gap. For acute wound healing, a predictable chain of events in a well-organized fashion is followed, whereas for chronic wounds there are prolonged Inflammatory or proliferative phases resulting in tissue fibrosis and non healing ulcers [10].

Also low level laser therapy is being extensively used to treat various medical ailments including wound healing. In the present study, an optical finer based He Ne laser irradiation system was designed, developed and evaluated for optimum tissue repair on mice excision wounds. The low intensity laser radiation has been investigated and used clinically to treat various pathologic processes such as tissue repair wound healing [11, 12, and 13]. In recent years the treatment of blood with low intensity laser radiation has become popular in a variety of clinical application due to the fact that it can modulate, improve microcirculation and increase activation of multiple enzymes [14, 15, and 16]. In spite of numerous reports on laser cellular effects, the interaction mechanisms of low intensity laser irradiation with erythrocyte and its components are still far from clarity.

There is presently a lack of information concerning molecule images of erythrocyte by laser radiation. The most prominent instrument among the scanning probe microscopes is the atomic force microscope (AFM). It has been widely applied to investigate biological processes and topographic structures of the surface of cell and biopolymers in both air and liquid physiological environments [17]. Living cells or tissues were exposed to both low power of red light and infrared light of wavelength ranging from 600 to 1070 nm involving diverse light sources in light-based therapy [18]. The red He-Ne laser is considered to have the best therapeutic effect at cellular level [19]. The effect of He-Ne laser low intensity radiation on kinetics of tumors growth has been experimentally investigated. It is realized that irradiation is more effective at an early stage of growth of a tumor and practically does not have any influence at a terminal stage of development of a tumor. Also, irradiation of animals with tumors by He-Ne laser low intensity radiation does not affect their life expectancy [20]. It is known that the respond of plants to light may vary depending on various parameters such as the duration of exposure (photoperiod), intensity, and wavelength of the light. In Photosynthesis process, sunlight is stored as energy in the bond between carbons [21]

3. Experimental Setup

This experiment is carried out by taking a 10:1 ratio of the proportion of Helium and Neon gas in the LASER gas mixture. By turning on the high voltage power supply to the He-Ne plasma tube, the He-Ne lasing inside the tube will be observed. A 14,000 V high voltage, DC power supply maintains a glow discharge or plasma in a glass tube containing an optimal mixture (typically 1:10) of Helium and Neon gas. The discharge current is limited to about 5 mA and the length of helium Neon Laser cavity is 0.5 m. Double Convex mirror is adjusted with optical fiber Optics that approaches to inlet of Monochromator and simultaneously mounted very near to laser tube.

By using the vacuum pumps to remove the gas particles and produce the partial pressure in laser medium then prepare it for gas filling at different pressures from 1.5 mbar to 3.0 mbar. Direct another He-Ne alignment laser beam through the center of the output coupler mirror to the center of the high reflector mirror. Adjust the high reflector so that it's reflected beam returns to the output coupler at the spot made by the alignment He-Ne laser as it enters the cavity. Setup the resonator configuration using two spherical mirrors output coupler mirror with a reflectivity 99% and high reflector mirror with

100%. The power supply is provided the high voltage of 10kV to start laser emission and 1-2 kV to maintain it. The process of light amplification and stimulated emission make Helium Neon laser work. Table-1 shows the important experimental parameters.

TABLE-1

Gas Ratio	He- Ne: 1:10, 1:9,1:8,1:7
Output Power	2.0 mW
Wavelength	632.8 nm
Polarization	Linear 500:1
Beam Diameter	0.49 mm
Beam Divergence	1.6 mRads
Pressure	1.5 - 03 mbar
Discharge Current	5 mA
Length of LASER Tube	8.50 inches
Operating Voltage	14000 to 1000 V
Operating Current Range	6 to 8 mA
Recommended Ballast Resistor	75K Ohms
Dimensions	13.8" long x 1.45" diameter

Meanwhile, when Laser is transmitted through optical fiber optics and approaches the monochromator, it is possible to measure a single wavelength that can be scanned through a wide wavelength range. It is digitally controlled and it counts the number of photoelectron with the help of photomultiplier tube (PMT). This apparatus is extremely sensitive and this type of detector multiplies the signal produced by incident laser light by as much as 10^8 from which single photons can be resolved. Photomultiplier tubes typically require 1000 to 2000 volts for proper operation [22, 23].

Eventually, the Intensity counter/photon counter is connected to the photomultiplier Tube. A single atom which we observe to see whether and when it emits a photoelectron .The intensity of a field is proportional to the rate at which intensity counter records photons probability per unit time.

Different wavelengths are now selected and the intensity at different pressures through the intensity counter is calculated. The objective is to investigate the correlation between the pressure, wavelengths and intensities of the Helium Neon LASER. By viewing the different wavelength numbers of the laser tube, the pressure and intensity of the discharge tube can be verified accurately. Therefore, the different wavelengths of red Helium-Neon LASER at different pressures with respect to intensities is thus experimentally calculated.

The purpose of this study is to calculate the intensity measurement of red Helium Neon LASER with respect to their wavelengths and pressures. Our focus here is to calculate the intensity of discharge tube at variant optimum pressures and wavelengths.

4. RESULTS & DISCUSSION

One of the aspects of present study is to get profile and to exhibit the behavior of the practical results. Here, the curve fitting techniques has been used to fit the results and depending on the parameters of the changing profiles. In this research, we have assembled 2.0 mW Helium Neon LASER and measured its intensity with few essential auxiliary components such as, rotary Pump, diffusion pump, He-Ne Laser tube, fiber optics, holder, mounts, photomultiplier tube, Monochromator, intensity counter, clamps for holding the beam fiber optics and photomultiplier tube.

A large Power Supply is applied from 14000-10,000 V for producing the discharge in Plasma Tube. The ratio of He-Ne is 10:1 and photomultiplier tube (PMT-R 9285) is connected with Monochromator with respect to 700 V. Back Ground counts of Intensity counter are selected 380 C/Sec. Resolution of Monochromator is 4 A^0 and supplied current, I = 8 mA.

Our main objective is to estimate the intensity of laser and examine the correlation between pressures, wavelengths and intensities of the Helium Neon LASER. In viewing the different wavelength numbers of the laser tube, the pressure and intensity of the discharge tube will be concurrently observed accurately.

TABLE: 2

CALCULATED INTENSITY CORRESPONDING TO VARIOUS WAVELENGTHS AND PRESSURES FOR HELIUM: NEON (1:10)

Wave Length (nm)	Pressure (1.5) mbar	Pressure (2.0) mbar	Pressure (2.5) mbar	Pressure (3.0) mbar	Remarks
492/486	5.17 c/sec	3.14 c/sec	3.71 c/sec	2.64 c/sec	**He/Ne**
492/505	2.14 c/sec	2.19 c/sec	2.12 c/sec	2.60 c/sec	**He/Ne**
501/486	18.27 c/sec	11.16 c/sec	12.26 c/sec	8.92 c/sec	**He/Ne**
501/505	7.57 c/sec	8.30 c/sec	7.20 c/sec	6.82 c/sec	**He/Ne**
706/717	23.15 c/sec	19.91 c/sec	17.23 c/sec	15.18 c/sec	**He/Ne**
706/724	8.46 c/sec	5.53 c/sec	4.19 c/sec	3.25 c/sec	**He/Ne**
728/717	10.17 c/sec	9.13 c/sec	7.23 c/sec	6.21 c/sec	**He/Ne**
728/724	3.71 c/sec	2.53 c/sec	1.72 c/sec	1.39 c/sec	**He/Ne**

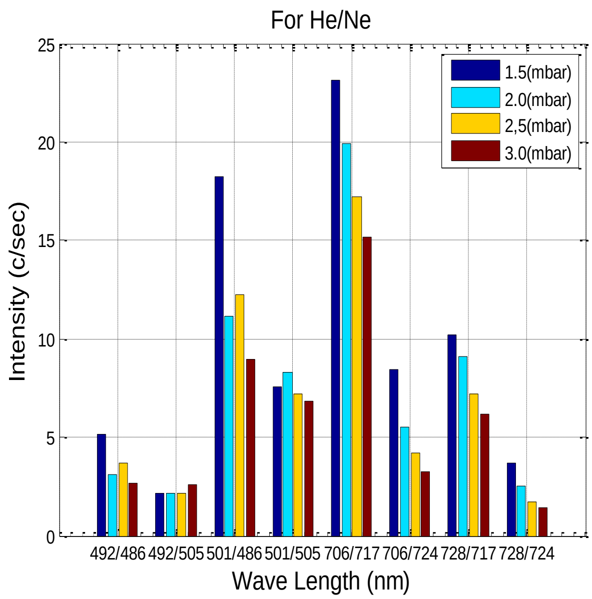


Fig: No: 01:- High Power Supply is applied from 14000-10,000 V for producing discharge in Plasma Tube. The ratio of He-Ne is 1:10 and PMT-R 9285 is connected with Monochromator with respect to 700 V. Back Ground counts of Intensity counter are selected 400 C/Sec. Resolution of Monochromator is 4 A0. Supplied current is I = 8

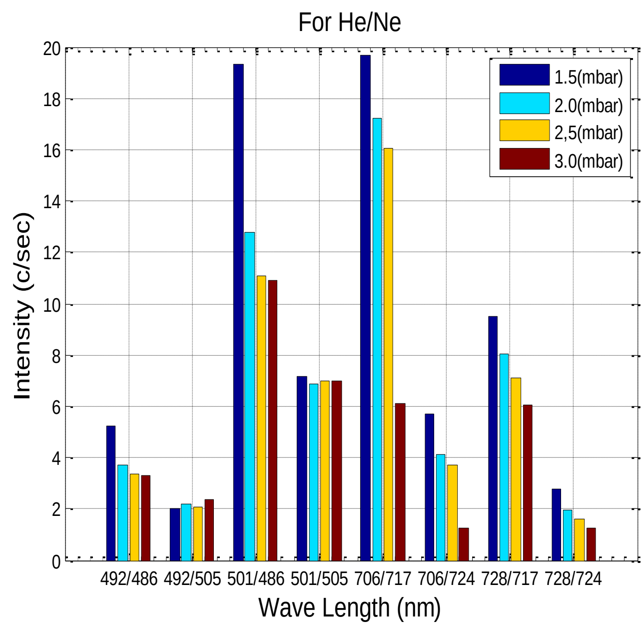


Fig: No: 02:- High Power Supply is applied from 14000-10,000 V for producing discharge in Plasma Tube. The ratio of He-Ne is 1:9 and PMT-R 9285 is connected with Monochromator with respect to 700 V. Back Ground counts of Intensity counter are selected 390 C/Sec. Resolution of Monochromator is 4 A0. Supplied current, I = 8 mA

TABLE: NO: 3

CALCULATED INTENSITY CORRESPONDING TO VARIOUS WAVE-LENGTHS AND PRESSURES FOR HELIUM: NEON (1:9)

Wave Length (nm)	Pressure (1.5) mbar	Pressure (2.0) mbar	Pressure (2.5) mbar	Pressure (3.0) mbar	Remarks
492/486	5.25 c/sec	3.70 c/sec	3.34 c/sec	3.31 c/sec	He/Ne
492/505	2.01 c/sec	2.19 c/sec	2.06 c/sec	2.38 c/sec	He/Ne
501/486	19.3 c/sec	12.77 c/sec	11.10 c/sec	10.89 c/sec	He/Ne
501/505	7.14 c/sec	6.9 c/sec	6.97 c/sec	7.00 c/sec	He/Ne
706/717	19.65 c/sec	17.22 c/sec	16.05 c/sec	6.13 c/sec	He/Ne
706/724	5.7 c/sec	4.10 c/sec	3.70 c/sec	1.25 c/sec	He/Ne
728/717	9.48 c/sec	8.06 c/sec	7.11 c/sec	6.04 c/sec	He/Ne
728/724	2.75 c/sec	1.98 c/sec	1.61 c/sec	1.24 c/sec	He/Ne

TABLE:4

CALCULATED INTENSITY CORRESPONDING TO VARIOUS WAVE-LENGTHS AND PRESSURES FOR HELIUM: NEON (1:8)

Wave Length (nm)	Pressure (1.5) mbar	Pressure (2.0) mbar	Pressure (2.5) mbar	Pressure (3.0) mbar	Remarks
492/486	6.82 c/sec	4.08 c/sec	4.12 c/sec	4.63 c/sec	He/Ne
492/505	2.02 c/sec	1.96 c/sec	2.06 c/sec	2.08 c/sec	He/Ne
501/486	24.35 c/sec	14.08 c/sec	13.05 c/sec	14.45 c/sec	He/Ne
501/505	7.13 c/sec	6.76 c/sec	6.75 c/sec	6.48 c/sec	He/Ne
706/717	14.39 c/sec	12.56 c/sec	10.96 c/sec	8.06 c/sec	He/Ne
706/724	3.46 c/sec	2.89 c/sec	2.25 c/sec	1.43 c/sec	He/Ne
728/717	0.75 c/sec	5.89 c/sec	4.80 c/sec	3.28 c/sec	He/Ne
728/724	1.01 c/sec	1.36 c/sec	1.08 c/sec	0.65 c/sec	He/Ne

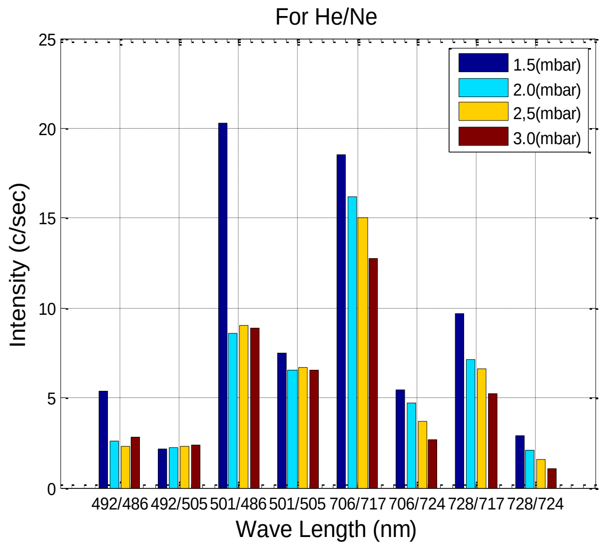


Fig:No:03:- Big Power Supply is applied from 14000-10,000 V for producing discharge in Plasma Tube. The ratio of He-Ne is 1:8 and PMT-R 9285 is connected with Monochromator with respect to 700 V. Back Ground counts of Intensity counter are selected 380 C/Sec. Resolution of Monochromator is 4 A0. Supplied current, I = 8 mA.

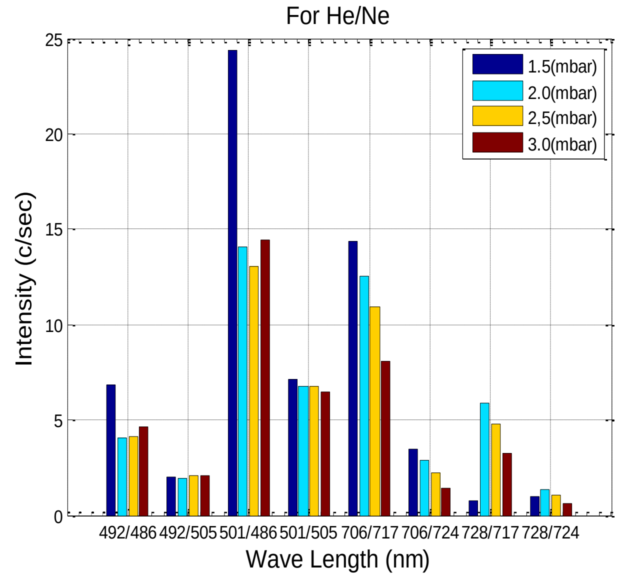


Fig:No:04:- High Power Supply is applied from 14000-10,000 V for producing discharge in Plasma Tube. The ratio of He-Ne is 1:7 and PMT-R 9285 is connected with Monochromator with respect to 700 V. Back Ground counts of Intensity counter are selected 380 C/Sec. Resolution of Monochromator is 4 A0. Supplied current, I = 8 mA.

TABLE:5

CALCULATED INTENSITY CORRESPONDING TO VARIOUS WAVE-LENGTHS AND PRESSURES FOR HELIUM: NEON (1:7)

Wave Length (nm)	Pressure (1.5) mbar	Pressure (2.0) mbar	Pressure (2.5) mbar	Pressure (3.0) mbar	Remarks
492/486	6.82 c/sec	4.08 c/sec	4.12 c/sec	4.63 c/sec	**He/Ne**
492/505	2.02 c/sec	1.96 c/sec	2.06 c/sec	2.08 c/sec	**He/Ne**
501/486	24.35 c/sec	14.08 c/sec	13.05 c/sec	14.45 c/sec	**He/Ne**
501/505	7.13 c/sec	6.76 c/sec	6.75 c/sec	6.48 c/sec	**He/Ne**
706/717	14.39 c/sec	12.56 c/sec	10.96 c/sec	8.06 c/sec	**He/Ne**
706/724	3.46 c/sec	2.89 c/sec	2.25 c/sec	1.43 c/sec	**He/Ne**
728/717	0.75 c/sec	5.89 c/sec	4.80 c/sec	3.28 c/sec	**He/Ne**
728/724	1.01 c/sec	1.36 c/sec	1.08 c/sec	0.65 c/sec	**He/Ne**

Generally the Helium Neon laser is operative on the processes of light amplification and stimulated emission. Stimulated emissions occur with the discharge of electricity into laser gas. The electrons in the discharge collide with the gas atoms imparting energy to them. These energized atoms are thus left in an unstable state in which some of their electrons have moved to a higher energy level. These excited atoms will quickly return to their ground state with the drop of these electrons to their normal levels. In principle, each time an electron drops in to a normal level it will emit a photon equal in energy to the difference between the levels.

This type of emission is referred to as spontaneous emission. Stimulated emission occurs when a photon of the proper energy strikes an already exited atom, creating an identical photon and this photon will subsequently travel through the laser gas causing even more stimulated emissions. The ever increasing reproduction of photons is called light amplification. With this process, the laser can effectively generate larger numbers of photons from relatively few spontaneous emissions.

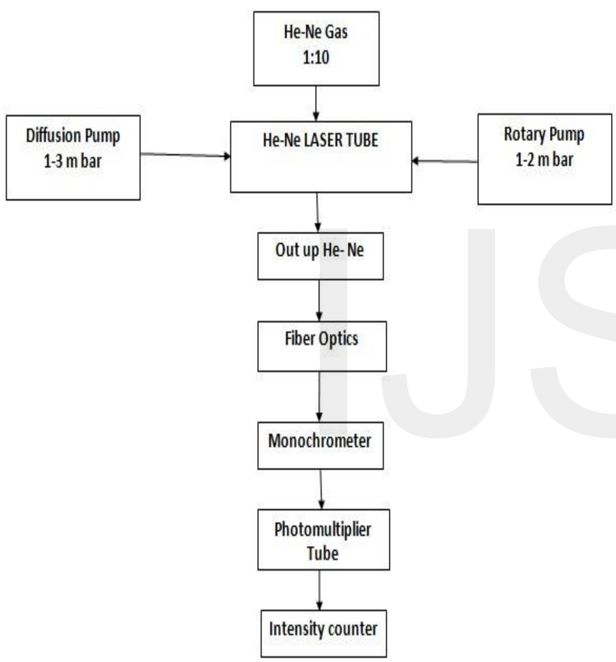
Neon atoms in Helium-Neon lasers are the source of laser light. Because stimulated emission only takes place with the availability of excited neon atoms. Generally speaking, the process will quickly come to an end unless the Neon atoms are replenished with energy. In this process the Helium atoms in the laser gas carry out the process of re-energizing the Neon atoms. This task is perfectly carried out by Helium because it has a meta-stable state (does not decay as quickly) corresponding to the energy required to re-energize the Neon.

5. Model Description

A high voltage power supply is turned on to the He-Ne plasma tube and the He-Ne lasing inside the tube can be observed. The Double Convex mirror is adjusted with fiber optics that approach to inlet of Monochromator and simultaneously mounted very near to laser tube through which laser induced and approached to inlet of Monochromator.

The red light emitting from the laser tube (632.8 nm) and coupled to the Optical fiber optics having a core diameter of 125 µm, the input end of the optical fiber optics is rigidly mounted very close to the laser tube.

Model:



Furthermore, the different wavelengths of He-Ne Laser at different pressures from 1.5 mbar to 3.0 mbar are selected and then the variant intensity through the intensity counter is calculated. The red Helium Neon LASER can be observed and the intensity measured with respect to variant wavelength and pressure experimentally and shown graphically.

6. Conclusion

The principle object of this research is determine the correlation between various parameters such as pressure wavelength and intensities of Helium Neon LASER tube and investigated the characteristics of He-Ne Laser for medical application. The intensities has been calculated with respect to different selected wavelengths and pressures at different ratios of laser. One of the aspects of present study is to use the Matlab to get profiles to exhibit the behavior of the practical results. We have defined the related formulae depending on the parameters of the changing profiles.

This paper comes out with results of the wavelengths values obtainable for various given He-Ne Laser of different intensity and pressure. Hence, these calculated values are set to be standard dosages corresponds to wavelength of He-Ne LASER are presented. These wavelengths values can be chosen for application to heal a patients wounds based on the severity of the wound. For Helium gas the calculated wavelengths of various pressure and intensity combinations gave values of 492, 501, 706 and 728 nm. For Helium gas the calculated associated wavelengths for various pressure and intensity variations gave 472, 505, 717, 724 and 486nm. Finally a broader categorization of the He-Ne Laser wavelengths are obtained. About eight wavelengths ratio corresponds to calculation of various combination of He-Ne Laser of pressure and intensity are given

References

[1] Pacific Rim ,Experimental Investigation of He-Ne Laser Noise, Shanghai, China, pp 01, 03,2009.

[2] K. A. Temelkov, N. K. Vuchkov, and N. V. Sabotinov, "Cross sections and rate constants for charge transfer into excited states," Plasma Process. Polym., vol. 3, no. 2, pp. 147–150, Feb. 2006.

[3] K.A.Temelkov, N.K.Vuchkov, R.P.Ekov, and N. V. Sabotinov, "Determination of characteristic constants for some basic processes in plasma—Diffusion, penning ionization, asymmetric charge transfer," J.Phys.D,Appl.Phys., vol. 41, no. 10, p. 105 203, May 2008.

[4] T. Sincich J. McClave. Statistics, page 215. Prentice Hall, 2000.

[5] L. Marzillier. Elementary Statistics, page 143. Wm.C.Brown Publishers, 1990

[6] E. Hecht. Optics, page 319. Addison-Wesley, 1998.

[7] Krassimir A. Temelkov, Stefka I. Slaveeva, and Nikolay K. Vuchkov, Analytical Calculation of Gas Temperature and Experimental Determination of Electron Temperature in Gas Discharge in Ne–He Mixtures IEEE Transactions on Plasma Science Vol. 39, NO. 3, pp. 831March 2011.

[8] Carolyne Pickler, Neil Edelman, Properties of the He-NeLaser, page 01, 2007

[9] E. Hecht. Optics, page 49. Addison-Wesley, 1998.

[10] A Falabella and R Kirsner, Wound healing, Basic & clinicaldermatology (Taylor and Francis, Boca Raton, Florida, 2005.

[11] T. Lundeberg, and M. Malen, "Low power He–Ne laser treatment of venous leg ulcers", Ann. Plast. Surg., vol. 27, pp. 535–537, 1991

[12] Lagan KM, Clements BA, McDonough S and Baxter GD , "Low intensity laser therapy (830 nm) in the management of minor postsurgical wounds: a controlled clinical study", Laser Surg Med， vol. 28, pp. 27–32, 2001.

[13] N.Kipshidze, H. Sahota, H. Wolinsky, et al, "Photoremodeling of atherosclerotic wall inhibits myointimal hyperplasia following balloon angioplasty", Circulation, vol. 90, pp.327–332, 1994.

[14] Siposan DG and Lukacs A, "Effect of low-level laser radiation on some rheological factors in human blood: an in vitro study",J Clin Laser Med Surg, Vol.18, pp.185-195, August 2000.

[15] Alexander N.Korolevich, Natali S. Dubina and Sergei I.Vecherinsky, "Investigation of the influence of low-intensity laser radiation on human blood microcirculation",SPIE, pp. 175—179, 2000.

[16] Kujawa J,Zavodnik L et al, "Effect of low-intensity (3.75-25 J/cm2) near-infrared (810 nm) laser radiation on red blood cell ATPase activities and membrane structure", Clin Laser Med Surg, vol. 22, pp. 111-117,2004.

[17] P.C. Zhang, C.L. Bai, Y.M. Huang, H. Zhao, et al, "Atomic force microscopy study of the structures of the entire surface of red blood cells", Scanning Microscope, vol. 9： pp. 981-988. 1995.

[18] M R Hamblin and T N Demidova, Mechanisms of low level light therapy, in: Mechanism for low-light therapy edited by M R Hamblin, R W Waynant and J Anders, Proc. SPIE 6140, 614001 (1{12) (2006)

[19] D H Hawkins and H Abrahamse, Lasers Surg. Med. 38, 74 (2006)

[20] YU.P. Meshaikin, T.O. Darchenko, K.V. Korobchevskaya, A.H. Arshakyan, C.V. Pushkarev 8" International Conference APEIE-2006

[21] Saiedeh Saghafi*, Amir fHeydari, Mohssen Nami, "Influence Of Laser Irradiation On Wheat Growth" September 2005, pp 283, Yalta, Crimea, Ukraine

[22] Anon, Photomultiplier Tubes: Basics and Applications (Second Edition), Hamamatsu Photonics, Hamamatsu City, Japan, (1999); pp, 60-65;

[23] Flyckt, S.O. and Marmonier, C., Photomultiplier Tubes: Principles and Applications, Photonis, Brive, France, (2002).101-123

[24] Introduction to Laser Technology Fourth Edition, C. Breck Hitz, J. Ewing, and J. Hecht 225 Copyright© 2012th Institute of Electrical and Electronics Engineers, Inc.