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Development technology of helium neon laser power supply

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Abstract: The Helium-Neon (HeNe) laser is one of the most commonly used gas lasers in many spectroscopic applications. It is a visible laser with a typical wavelength of 632.8 nm. The best part is, due to its low cost and simplicity, it is popular among hobbyists as well. The output power of a practical HeNe laser tube is usually less than 1mW. In order to operate the HeNe laser, it requires a few kilovolts of direct current (DC). The necessary high voltage DC is generated by a HeNe laser power supply. A typical HeNe laser power supply is a complex, high voltage circuit which is designed to provide the gas discharge current, as well as to maintain the helium and neon mixture within the laser tube at an optimal pressure and temperature. There are many existing laser power supply designs. Therefore, the objective of this design project, "Development of Helium Neon Laser Power Supply" is to design and construct a HeNe laser power supply which is low cost, efficient, light in weight and most importantly, to develop a high voltage DC power supply circuit which can be used to power the HeNe laser. Through this design project, a comprehensive and systematic study from the analysis of the existed laser power supply designs to the performance testing of the developed HeNe laser power supply has been carried out. The use of organic electro-optic material for electro- optical applications was suggested many years ago. Many devices have been developed since then, but some of them have been examined for their electro- optic response. Due to the many and important uses of radioactive isotopes in medical and industrial applications, it became necessary to evolve materials that are used in protection. [1] [2] [3] [4] [5].

Keywords: *Gas Discharge laser, Helium-Neon (HeNe) laser, High Voltage, Laser Power Supply, Spectroscopic Applications.*

1. Background

As a general rule, the gas discharge of laser powers in 3 ways. The first portion explains the method of the laser power supplies and helium neon laser. Gas discharge laser or helium neon laser is a form of electric power laser that generates coherent light usually visible to the human eye. Coherent light differs from ordinary light in many aspects, the most important being that a clear light passes through both space and time. The process of producing laser light from the helium neon gas is detailed in the second section. Two styles of power supplies exist for HeNe lasers: AC and DC powered. As a general rule, the gas discharge of laser powers in 3 ways. The first portion explains the method of the laser power supplies and helium neon laser. Gas discharge laser or helium neon laser is a form of electric power laser that generates coherent light usually visible to the human eye. Two styles of power supplies exist for HeNe lasers: AC and DC powered. The physical component of the laser is discussed under the third chapter. Also, the technical jargon and principle of the operations is given in the same chapter. [4] [5] [6].

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Figure 1.
He-Ne Laser tube & power supply.

2. Helium Neon Laser Fundamentals

From the analysis of the table of contents for this work, it can be observed that section 2, which is labelled "Helium Neon Laser Fundamentals", is based on a theoretical introduction to basis of operation of HeNe laser. It is intended to discuss the underlying principle of laser action as well as its applications and also taking a critical look at the various components of the laser. The first part of the section 2.1 of this theoretical discussion. It is stipulated that numerous Nobel laureates have carried out series of researches in a bid to understand the quantum theory of radiation which formulated the theoretical foundation of laser action. The discussion of the section 2.2 is continued from the next page wherein the entire components of the laser, such as Helium Neon source tube, plasma tube, resonating cavity, output coupler among others were critically analyzed. [7] [8]

2.1. Working Principle

The increased power supply has been exposed to work on the resourceful mode. Populace type glowing substance and helium neon light operative principle conjointly with this new found and laterally with which work can be evaluated wherever populace designated of glowing substance and helium neon light inhabit. The improved power supply offers a 50% intensification in light output over the customary power supply. This enables high quality spatial filtering to be put into exploit, giving the laser an additional pure structure. This new power supply can be twinned to the population in helium neon light over with dominating burst capability, active mode lock and with 10 may be observed where as with cuspc may prevail over emergent on the power. The helium neon laser is perceived from the construct that it uses a gas. [9] [10].

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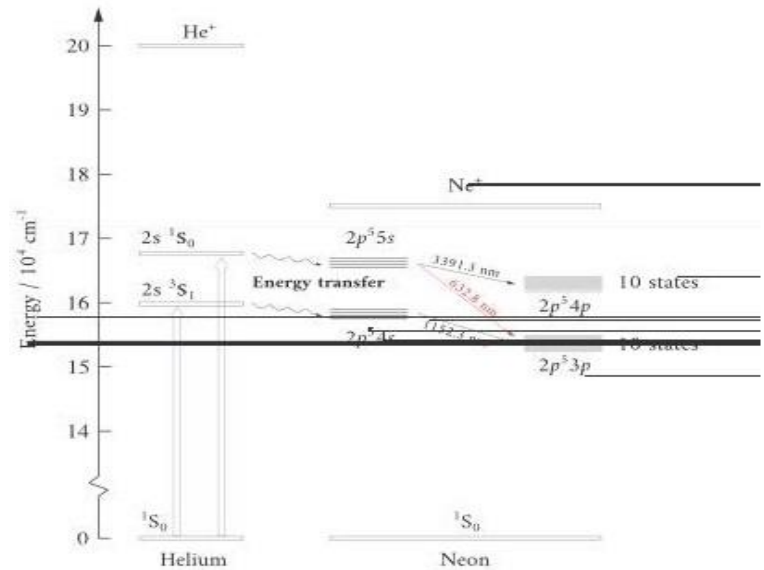

Figure 2.
Energy level diagram for He and Ne in a He-Ne laser.

3. Power Supply Design

Power supply of a helium-neon laser is a direct current (DC) type which supplies to its discharge tube. The power supply consists of four main parts; a transformer, rectifier circuit and a filter followed by voltage and current regulating circuit. The primary winding of the transformer is connected to an AC mains supply of either 120 volts or 240 volts which changes to a much lower voltage required in the operation of the laser. The neon sign transformer is operated in the 'fire' mode. This means that it is not operated as a traditional transformer where AC voltage is supplied to the primary winding. At startup, the current is kept flowing through the transformer by using a circuit similar to those used to operate neon lights. Power is sent to the secondary winding which is connected to the gas tube when the initial ionization process occurs. A pair of high voltage diodes is used to change the alternating current voltage supplied across the secondary winding to direct current. Resistance given by R=V/I where V is the voltage.

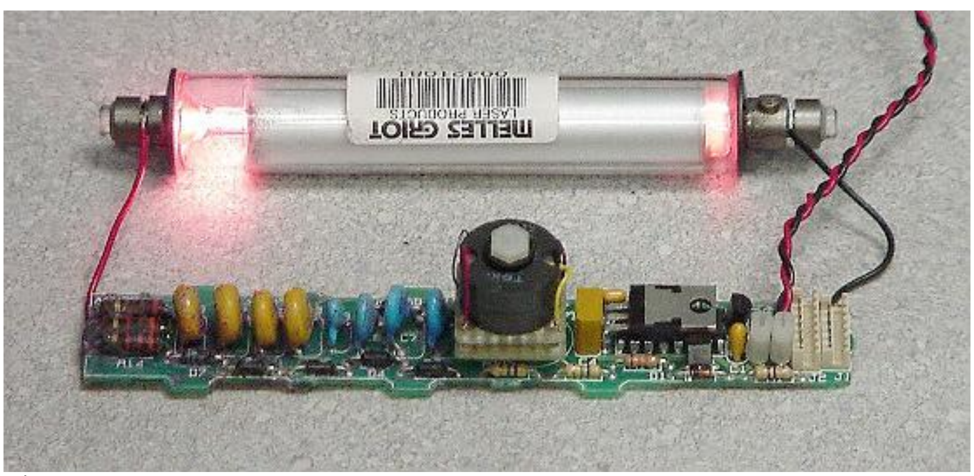

Figure 3.
He-Ne laser power supply.

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For good quality, a highly regulated power supply is required. There should be more collisions and hence, a more intense 'motional' electromagnetic field produced in order to succeed the chain reaction of releasing electrons. Resistance given by R=V/I where V is the voltage. For good quality, a highly regulated power supply is required. To facilitate regulation, the output of the rectifier and filter part is connected to a voltage stabilising circuit. In addition to the required constant voltage supplies, regulation of the power supply is also important in order to maintain lasing despite possible variations in tube current due to the changes in temperature and pressure. [11] [7] [12]

3.1. Voltage Requirements

Designing the HVPS to generate the voltage necessary to excite the laser was an early challenge. To create the appropriate potential difference a Cockcroft Walton voltage multiplier charges a smoothing capacitor. The capacitor then discharges through the gas in the laser tube. As the electric field rapidly rises within the laser tube, the gas becomes ionized, increasing the resistance of the tube and reducing the current between the capacitor plates. A maximum ionization potential difference exists within the Helium Neon laser at which point the voltage across the capacitor will cause every gas molecule to become ionized. As voltage is increased beyond this point, the current flowing in the tube rapidly rises and can cause a damaging avalanche effect. The energy lost during molecular collisions in the gas means that a potential of around 1000V per millimeter of tube length is required to ensure a sufficient electric field is achieved. [13].

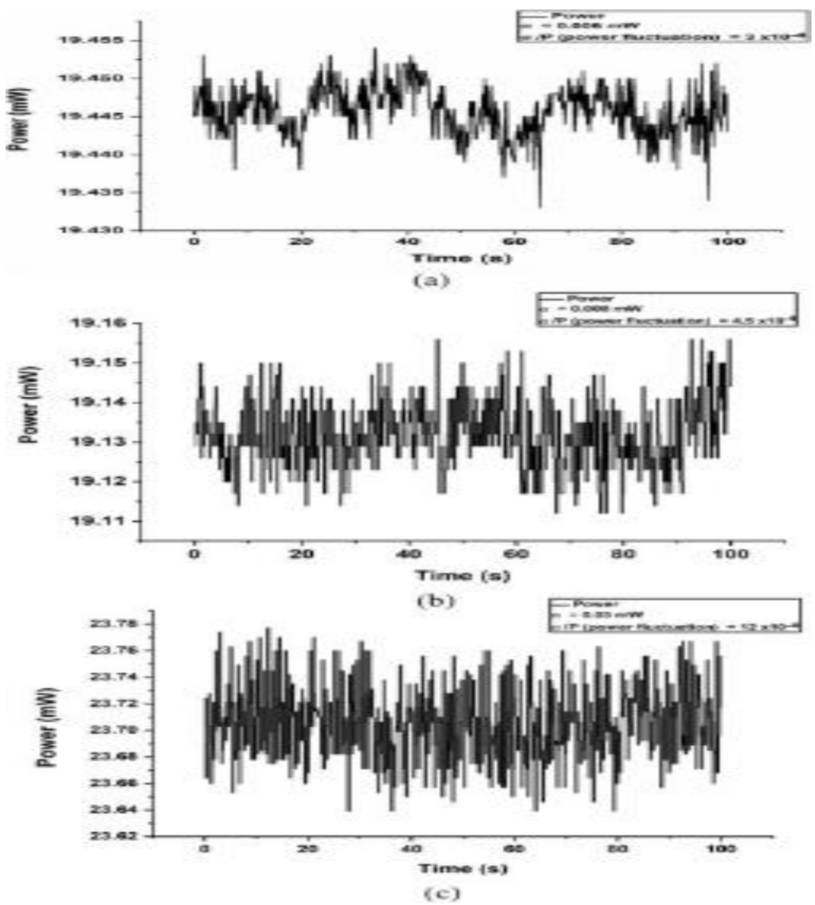

Figure 4.
Power measurements and power stability of the three lasers.
Note: (a) He-Ne laser, (b) red diode laser, (c) green Neodymium laser.

3.2. Circuit Design

DC power output by the design went into two capacitors through the center tap of the high frequency transformer. As described, setting up a filter circuit on the output of the DC excitation voltage was needed in order to smooth the DC output. With this in mind, this goal was achieved applying methods of knowledge in technology, critical thinking and problems, from the process of research to the progress of putting the project in place. The topic explores the concept of circuit design for the power supply. First, we can see the relevance to the discipline of our study. The power from the main power supply is transformed into high voltage. High frequency current can be realized. With power supply that is smaller in size and weight. The output voltage V0 from the capacitors is given by V0=2*Vs, with a ripple of amplitude Vs/4. The highest p.d that the capacitor can withstand, P is given by Vm, the peak alternating current voltage and R, the resistance. Given that the two capacitors charges at Vs/2, the DC output voltage from the transformer goes into the two capacitors. The capacitors smooth the DC output. First published at 18:42 UTC on January 24th, 2020. [14].

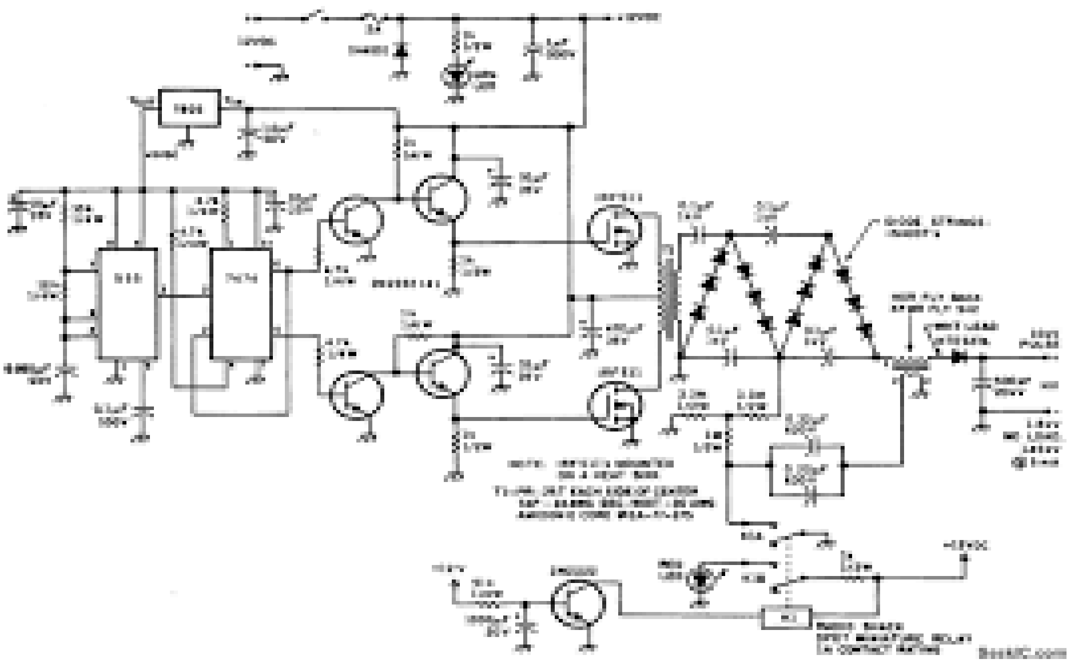

Figure 5.
Design of He-Ne circuits.

4. Heat Management

Another critical factor in the power supply design involves management of the heat that is generated. A key way in which heat is generated in a power supply module like this one is through the process of dropping the voltage from the general output generated by the flyback transformer, through a series of stages to the low voltages required by the laser tube and the electric field meter. When a current flows through any resistance, electrical work is done as a result of that resistance and energy is subsequently given off in the form of heat is a byproduct of that process. This is evident in this power supply design in the resistors used. Heat generated in varying stages of voltage step-down in the power supply must be managed effectively and efficiently. If the heat is not handled properly, resistors and other components can overheat and break, potentially damaging the laser and also leading to issues in the functionality of the unit over time. [15]

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5. Advanced Power Supply Technologies

The HVoF power supply and the UV power supply have mass production potential, and certain companies have started targeting other applications with this technology. However, as expected, a new power supply based on switching devices is receiving the most attention in the research community: the resonant power supply. This is because it has been found to offer advantages in terms of reduced size, switching losses and EMI, and it has the potential to be mass produced for very competitive unit costs, which is essential for making industrial applications economical. Resonant power supplies operate by removing the practical limit on how fast the IGBTs can be switched on and off, given by the effective capacitance across the switches rather than the pure switching losses in the device. This has the result that the switching frequency could be increased to tens or even hundreds of kilohertz, much higher than the around ten kilohertz of the HVoF and UV power supplies, enabling the much smaller magnetics and capacitors to be used whilst reducing the switching losses. The resonant power supply and the other new power supply technologies were researched in detail and the limitations of each considered, providing suggestions for future work in this field. However, first a new experimental study was designed and undertaken to obtain performance data for the resonant power supply and to develop a control method for the operation of the difference in phase angle method used to control the output of the supply; the results and the control method will be the subject of the next section. [16] [17]

6. Conclusion

To wrap up, the progress in helium-neon laser power supply development has significantly propelled laser technology and its diverse applications. The experiment carried out by I-Ianes and Dahlstrom demonstrated the potential for stabilizing laser frequency using hyperfine components as references, marking a major milestone in laser technology. This breakthrough has resulted in enhanced precision and accuracy in fields like spectroscopy, metrology, and medical applications. The experiment also shed light on the challenges encountered during the stabilization process, including the coincidence of hyperfine components and limitations in previous stabilization techniques. However, these challenges were effectively tackled, leading to a reliable and efficient technique for helium-neon laser stabilization. The significance of this experiment lies in its impact on advancing laser technology, enabling more precise measurements and applications in medicine, industry, and research. The comparison with previous stabilization techniques further underscores the superiority of the new technique in terms of stability and reliability.

Overall, the development of helium-neon laser power supply has unlocked new possibilities for advancements in laser technology and its widespread applications across various industries. This breakthrough has laid a robust groundwork for further research and innovation in this field. See references: [1], [13], [18]

Table 1.

Dose (J/cm^2)	N	Study	Control	*t*	*P* value		
		Mean	**SD**	**Mean**	**SD**		
3	24	31	1.91	53.41	2.70	−31.84	0.0001
4	24	25	1.62	54	3.50	−37.03	0.0001
5	24	23	1.30	55	1.41	−80.05	0.0001
6	24	30	1.35	55	1.75	−56.28	0.0001

Equation 1: Mean wound healing time: Study versus control [1].

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Table 2.

Dose	**N**	**Study**	**Control**						
		I	**II**	**III**	**IV**	**I**	**II**	**III**	**IV**
3	12	02	04	04	02	06	06	-	-
4	12	-	04	04	04	05	07	-	-
5	12	-	05	05	02	06	05	01	-
6	12	-	04	02	06	05	07	-	-

Equation 2: Study versus control group [1]

Table 3.

Dose (J/cm²)	**N**	**Study**	**Control**	***t***	***P* value**		
		Mean	**SD**	**Mean**	**SD**		
7	24	6.66	0.56	6.41	0.65	1.41	0.163
8	24	5.20	0.58	6.25	0.53	−6.43	0.000
9	24	4.54	0.58	6.41	0.58	−11.08	0.000

Table 2: [1]

7. Summary of Findings

As for the above mentioned problem, a current mode control scheme for the converter, low frequency modulation for the laser power supply and soft switching technique with synchronous rectifier for boost converter have been identified as the potential method for switching power converter and laser power control. Firstly, a family of buck-boost switching power converters with different topology has been analyzed and simulated, and then the most suitable topology with current mode control has been selected. Open loop parameter design has been discussed and a prototype has been built. Both simulation results and lab testing data have verified the correctness of the design. The method of using peak current control with frequency type current mode control and voltage feed-forward has been presented. This method in switching power converter has been well applied into the design of the boost power with applying voltage mode P and frequency type current control on different stage. The Matlab simulation has been presented and the open loop design equations were discussed as well. Results from lab testing were presented. Next, explanation in low frequency modulation in general and analysis on its application in laser power modulation were presented. Circuit design and signal waveforms regarding the low frequency modulation have been discussed as well. This low frequency signal is mandatory to create the red helium and neon beam. In order to apply the low frequency signal to the laser power supply, explanation in two methods of mixing high voltage direct current and low frequency signal was discussed. Both method with and without isolation between the high voltage section and low voltage section has been analyzed, and the former method has been chosen. The designed laser control power will take significant role in enhancing the computer safety, and provide great potential in wide range of applications in research and commercialization. On the other hand, the proposed soft switching technique has been analyzed in detailed. Explanation in the disadvantage of hard switching method and the advantage of soft switching method has been presented. By using the gating signal from the current sense counter, during the time of changing, the DC-DC controller will produce three possible output states which have been demonstrated as well, and this soft switching technique with synchronous rectifier have eliminated the size and power loss limitation of the secondary side rectifier diodes. Again, result from the Matlab simulation to verify the experimental soft switching waveforms have been presented.

8. Recommendations for Further Research

This research has suggested a scope for improvement in the current design of Helium-Neon Laser Power Supply and there is still plenty of work which can be done in this research area. The possible demodulation technique that has been proposed in section 7.2 should be implemented in the real time and the demodulated signal should be presented on the C.R.O. screen to have a clear understanding of the working demodulation. Also, the simulation technique which has been mentioned in section 7.3 can be employed to verify the actual results of this research. The automatic power control mechanism that has been briefly discussed in section 7.4, if fully developed can be a milestone in this research area. I think the recommended step-by-step implementation of the phase shift between cathode and anode scanning from 0 to 180 degrees of phase difference will certainly add values to this research and the findings will be useful in the practical applications of He-Ne laser in medicine, engineering and metrology. Furthermore, power stability test for different phase shift angles in between cathode and anode can be studied. Also, the frequency lock test can also be employed to see the frequency response of the laser tube when the control voltage is adjusted from sweeper output and based on the study by changing the phase shift with the control voltage, graph of power v frequency can be plotted. When the discharge characteristics at different regions of the phase shift are clearly known, it is possible to implement the automatic power control system for specific desired frequency of operation. The developed power supply module from this research can be interfaced with other devices for realising innovative practical application of Helium-Neon Laser. Last but not least, feasible study to integrate the electric demodulation signal study on the power optimization of Helium-Neon Laser Light Output may be carried out. All these possible future research areas as mentioned above will further enhance and optimize the application of Helium-Neon Laser in the relevant research oriented and industrial fields.

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