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Construction of V-Shape Electrodes Nitrogen Laser

Kamal H. Latif
Scientific Researcher
Wissam H. Mahdi
Lecturer Assistant
Education College for Girls
Kufa University
Mahdi.wissam@yahoo.com

Abstract

The laser system has been constructed and operated locally to get ultra-violet laser pulse at 337.1 nm. A short laser channel, low pressure system with V-shape electrodes design will be described in detail. We studied several discharge parameters such as gas pressure applied voltage and capacitance of Blumlein capacitors. The best results obtained with applying voltage 10 KV, gas pressure 60 mbar, electrode spacing 1 cm, and repetition rate 1 PPs, no gas flow and E/P ratio 222 V / (cm.torr).

Introduction

The pulsed molecular nitrogen laser is a gas discharge laser that produces ultra violet laser output at 337.1 nm. This laser operates on the ($C^3\Pi_u \longrightarrow B^3\Pi_g$) vibronic system, which involves a change in both electronic and vibration energy level [1, 2, 3, and 4]. A pulsed nitrogen laser has been constructed at relatively low cost. This design incorporates V-shape electrodes to ensure even transverse discharge at low pressure closed system and produces superradiant emission at 337.1 nm. Our nitrogen laser was constructed for spectroscopy studies and oil spill detection.

General Description

The laser cavity consist basically three plates of Perspex with 30 cm length, 12 cm width and 1.5 cm thick for each one that past with together. The mid plate has a rectangular hall in center with dimension (24.6 and 1.5) cm to make the laser channel and two circular hall one on each side to do as output aperture. Other plates do as a cover of laser channel for both sides. The electrodes were constructed with V-shape edge to great high current pulse inside the laser channel and operate the laser in low range of operating high voltage region. Also v-shape electrodes can be generated self-preionization to obtain high stability electrical discharge. The electrodes were fixed in a rectangular hall of mid plate and connected with Blumlein capacitors by copper foil. The laser cavity fixed directly on the copper plates of Blumlein capacitors by pressing.

Figure (1) shows the photographic picture of our laser system, it illustrates the discharge circuit is conventional flat plate, laser head and spark gape switch.

The flat plate transmission line was made of 0.42 mm thick fiber glass epoxy dielectric and 0.03 thick of copper foil on both sides to form Blumlein circuit as shown in figure (2). The capacitors are formed between the top and bottom copper foil on (30 * 46 * 0.042) cm printed circuit board (P.C.B) the top and bottom foil were etched for 3 cm around the edge and 3 cm strip was removed from middle of the top metal. The two equal capacitors have value 5.34 nF.

1-Spark gap
2-Electrode
3-Pressure connection
4-Mirror
5-Laser cavity
6- PCB
7-Bybase coil
8-quartz (window)

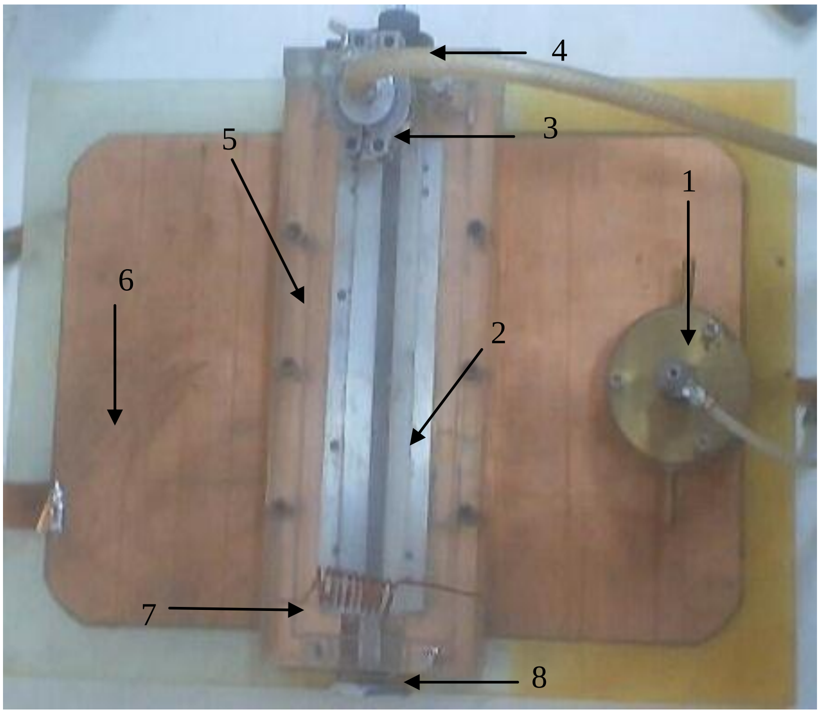

Fig. (1): Photographic picture illustrating the cavity of laser with PCB and spark gap.

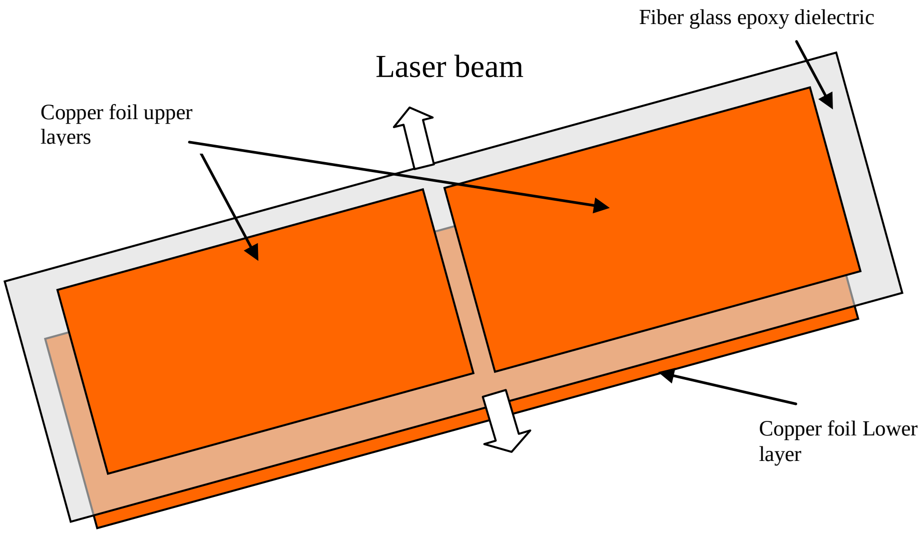

Fig. (2): . Schematic of Blumlein Circuit

Figure (3) shows the geometrical shape of the electrode with it's dimensions. The both electrodes have one sharp edge as a V-shape with angle 26.5^0 and 24 cm length, the separation between electrodes is 1 cm. this design will be reducing the chance of undesired arcing that could be made from the far edges of the electrodes.

The output laser pulse will be getting out from two sides (both ends of laser channel). A totally reflecting mirror was used in one end and transparence quartz in the other side to direct and increase the output laser pulse. The self triggering spark gap was used in our system as a fast switch.

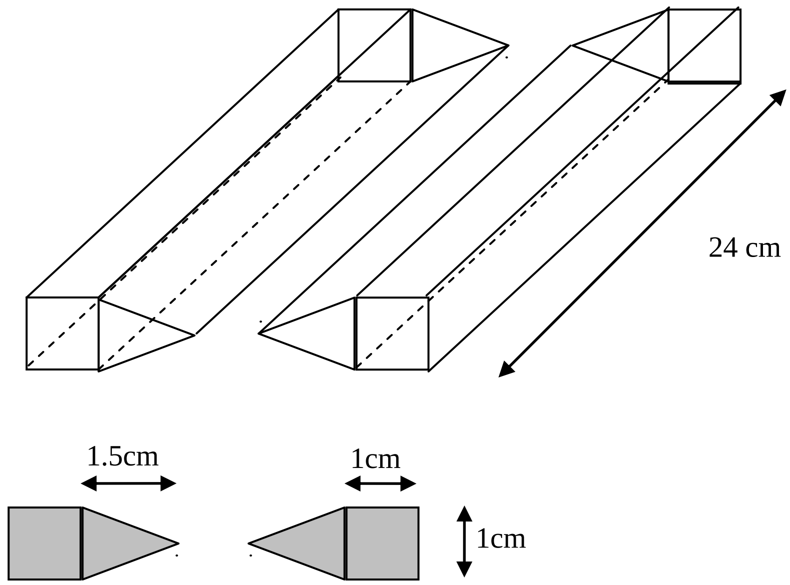

Fig. (3): The geometrical shape of the electrode.

Experimental Results

At the beginning of operating the system, the arc mode (hot spot) has more chance to be generated and no lasing action was occurred because the contaminate inside the laser channel, moisture, molecule of gases that trapped in the wall of cavity and electrodes and out gassing from the channel material. During operating of system the hot spot decreases slowly.

Figure (4) shows the variation of the number of laser pulse for every ten shoots of discharge pulses as a function of the number of shoots. The number of laser pulse for every ten shoots increases with increase the total number of shoots because the electrical discharge operation will be heating the gases inside the laser channel and the channel material that helping to get out of trapped gases on the wall of cavity and moisture[5]. By evacuating the laser channel continuously, all undesired gases and defects will be removing. The laser channel was cleaned gradually. When the laser channel is cleaned, all the shoots result laser pulse.

Figure (5) shows the photographic picture of laser head at firing that appears the distribution of electrical discharge and the florescence spot of laser pulse on the white paper.

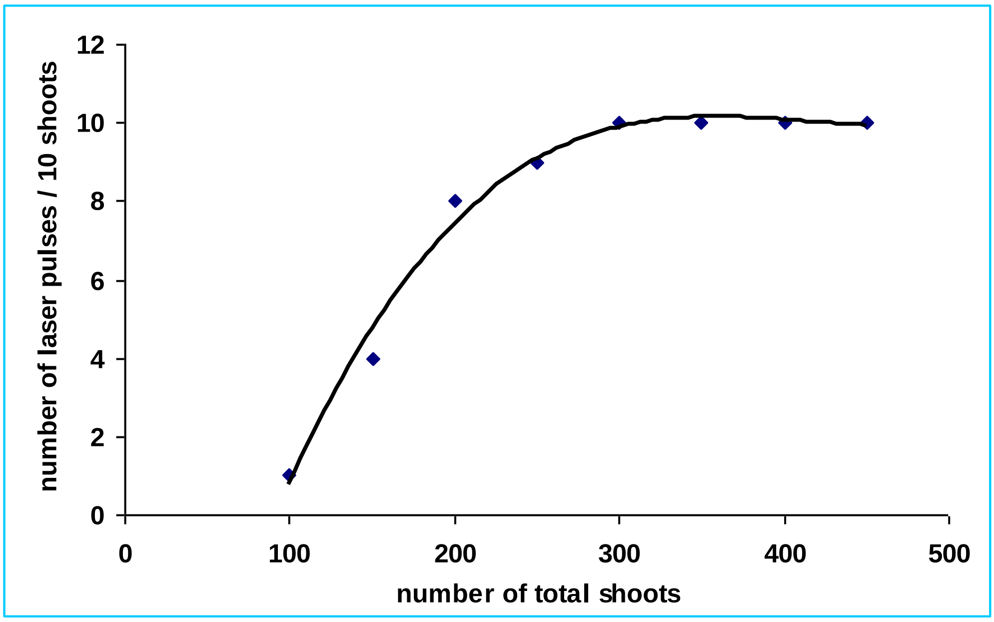

Fig. (4): The variation of the ratio of number of laser pulse to ten discharge pulse as a function of number of shoots.

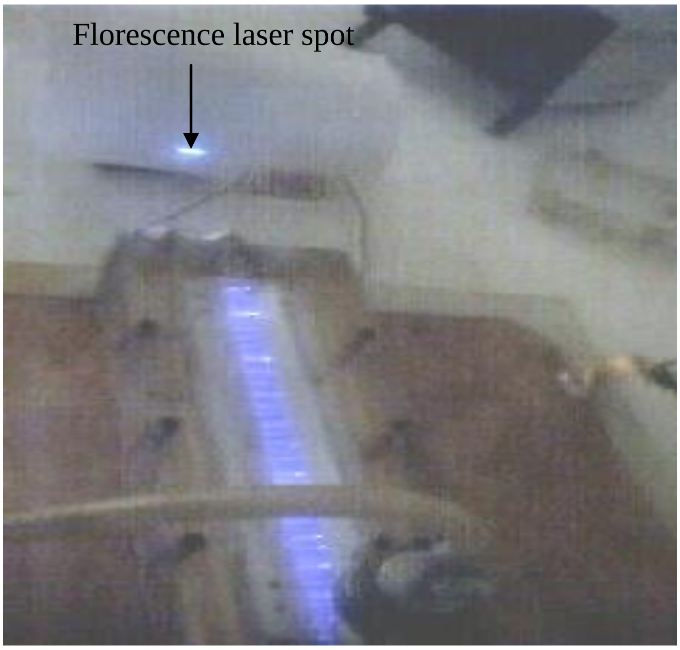

Fig. (5): Photographic picture of laser head at firing and spot form of laser pulse.

Figure (6) and figure (7) show the dependence of the peak laser power on the capacitance of storage capacitor C_1 and switch capacitor C_2 respectively.

When C_2 is a constant value (C_2 =1 nF), the peak power of laser increases rapidly with increasing C_1 until it reaches to a certain value (C_1=C_2=1 nF). After that, the peak power increases very slowly with increasing C_1. The energy in storage capacitor C_1 converts to laser energy before reaching the saturated point [6, 7]. When the stored energy is in excess of the saturated value, most of it will be wasted as shown in figure (6).

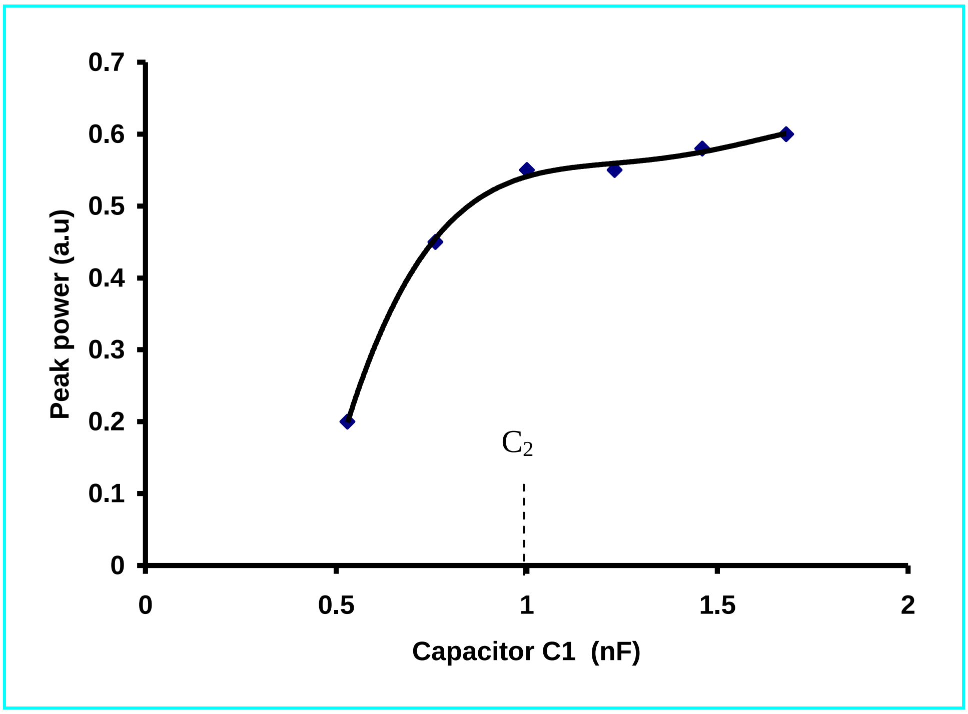

Fig. (6): Dependence of peak power laser on the C_1 for C_2=1 nF at applied voltage 10 KV and gas pressure 60 mbar.

When C_2 increases (at C_1 is a constant value C_1=1 nF), the peak power will increase. The peak power decreases in excess of the optimum value of C_2 (C_1=C_2=1nF) as shown in figure (7). The interpretation of this behavior based on the fact that the starting voltage of the laser discharge depends on the rise time of the anode voltage, and actually the starting voltage decreases gradually with increasing the value of the C_2.[1,6,8]

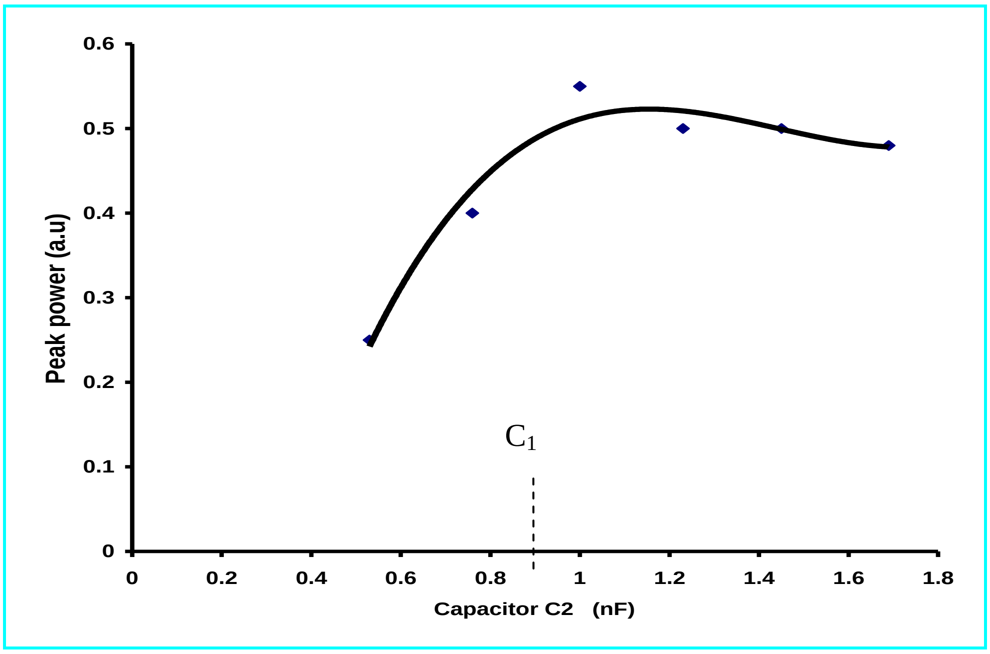

Fig. (7): Dependence of peak power laser on the C_2 for C_1=1 nF at applied voltage 10 KV and gas pressure 60 mbar.

Figure (8) illustrates the effect of the applied voltage on the peak power of the laser at a constant value of pressure 60 mbar. It is clear that the peak power of laser increases with the charge voltage to reach a certain value then begin to decrease slowly. This behavior can be interpreted according to the fact that the output power is proportional to б (T_e) and N_e where N_e is the electron density; б (T_e) is the sum the electron excitation cross section to the upper and the lower laser level. The output power increases linearly with N_e; N_e depends on the current passed through the laser channel which depends on the applied voltage. This means that the output power increases linearly with applied voltage. The deviation from linearity originates from the voltage dependence of T_e and therefore, б (T_e) [2, 9]. The electron temperature (T_e) can be calculated by equation (1) [3].

$$K\,T_e = 0.11\,(E/P)^{0.8} \quad \text{eV (E/P in V/cm torr)} \quad \text{------------} \quad (1)$$

The equation (1) determines an effective electron temperature which is sufficient to predict the observed rates of ionization in nitrogen. Since the excited states associated with the laser are close to ionization limit, one would expect the same electron temperature to closely approximate the electron excitation of these states [4, 6].

At increasing applied voltage in excess the certain value, the peak power will decrease because the rate of ionization and chance of creating arc will increase, in addition the cross section of excited states will decrease, so the most energy will wasted.[10]

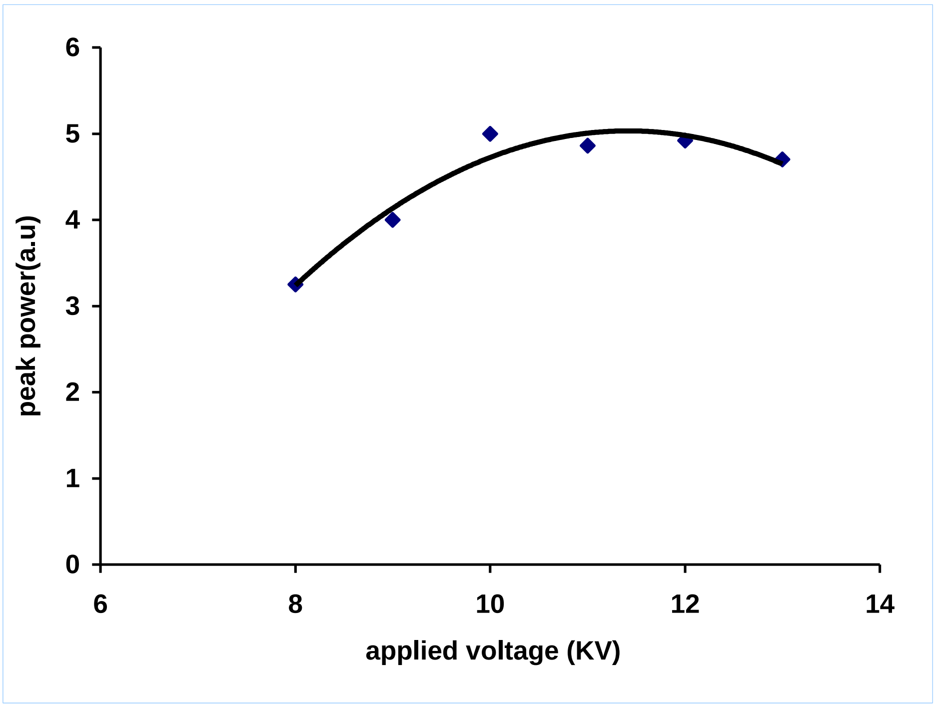

Fig. (8) Shows the variation of peak power as a function of the applied voltage at pressure (60 mbar).

The peak laser power as a function of Nitrogen pressure at certain applied voltage (10 KV) is shown in figure (9). We note that there is an optimum value of pressure to get the maximum peak laser power, because there is an optimum value of E/P for each design of N_2 laser system within the fixed range of E/P (180-250) V/ (cm.torr) because the electrical power to the laser tube is maximum when the impedance of the discharge is about equal to the impedance of the driving electrical circuit [4, 11]. So, the electrical power is a maximum when E/P ratio is about 222 V/(cm.torr) and thus the impedance–matching condition is reached in coincidence with the discharge conditions that are most favorable for the production of laser emission. So the changing pressure at applied voltage is constant will effect on the E/P ratio.

At pressure greater than the optimum value, the discharge in the laser tube becomes non uniform with concentrations of current flow. In the extreme limit of very high pressure, the discharge degenerates into one or more spark.

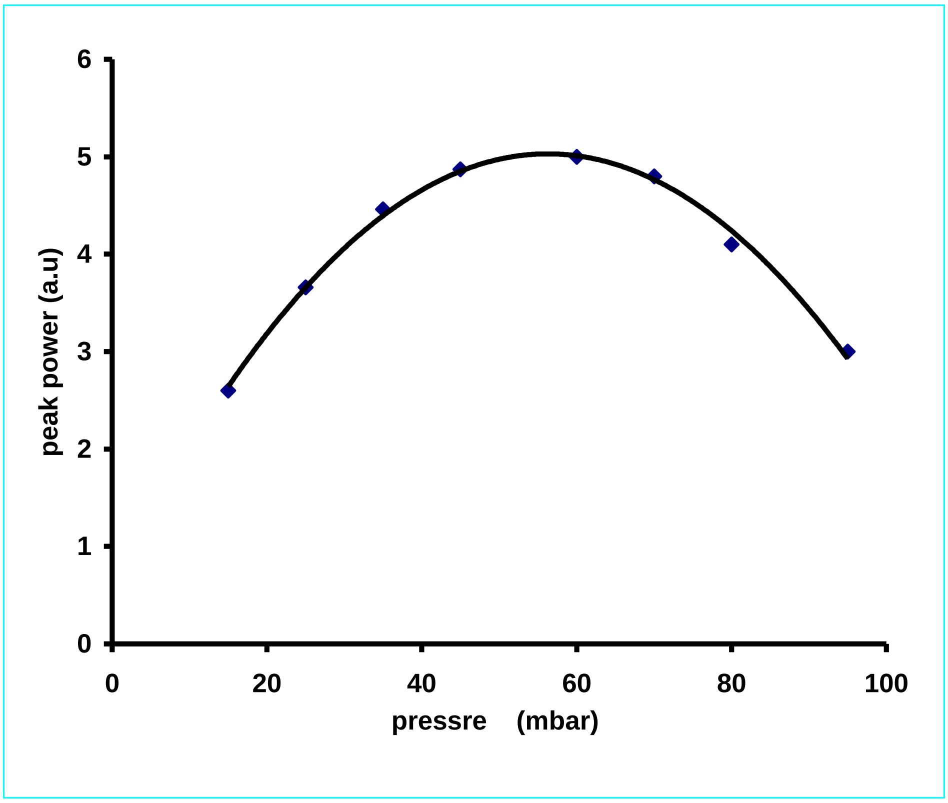

Fig. (9): The peak power versus gas pressure at the applied voltage (10 KV).

To determine the best E/P ratio, we will draw the peak laser power as a function of E/P ratio at constant value of applied voltage once and gas pressure in another time as shown in figure (10) and figure (11) respectively. We note two different behaviors of the laser power with variation of E/P ratio.

In figure (10) the peak laser power increases with the decreasing of E/P ratio (i.e. when the pressure increasing) till to reach the maximum value of power. This value determines the best ratio of E/P. The laser power falls rapidly with decreasing E/P ratio less than optimum value. The increasing pressure will increase free electrons in laser medium (electron density N_e). So, the current density (J_e) passed through the laser channel will increase according to equation (2) [9].

$$J_e = N_e e v_d \qquad \text{-------------------} \quad (2)$$

Where: e is the electron charge.
v_d is the average electron drift velocity .

Also the increasing pressure will increase the laser voltage [12] that leads to increase the electron drift velocity according to equation (3) [9].

$$v_d = \mu . E \qquad \text{-------------------} \quad (3)$$

Where: μ is the mobility of the electron.
E is the electric field.

So, the increasing current density will increase the number of collision between the electrons and molecules and increase the number of the excited molecules, i.e. the population inversion will increase. Also, the current determines the discharge type that can be occurred inside the laser channel, this fact can interpret the rapidly fall in curve.

In figure (11) the peak laser power increase slowly with E/P ratio, when the applied voltage is variation. There are semi- stable region in curve, then it begin decrease with increasing E/P ratio.

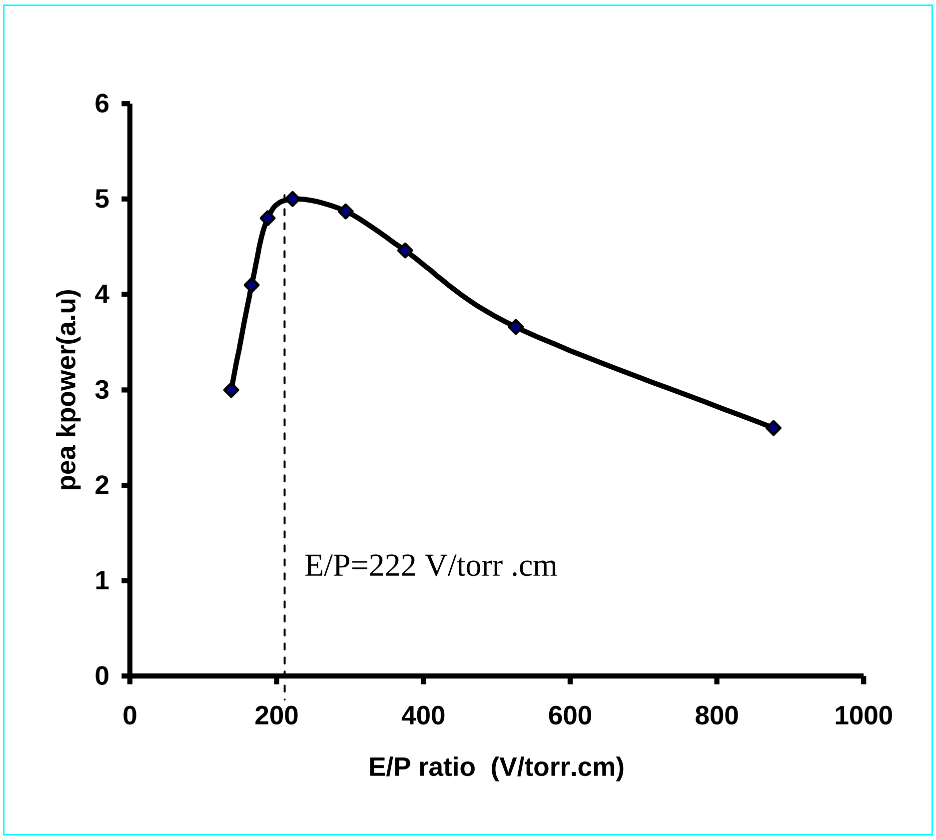

Fig. (10): The variation of peak power as a function E/P ratio at applied voltage constant (10 KV).

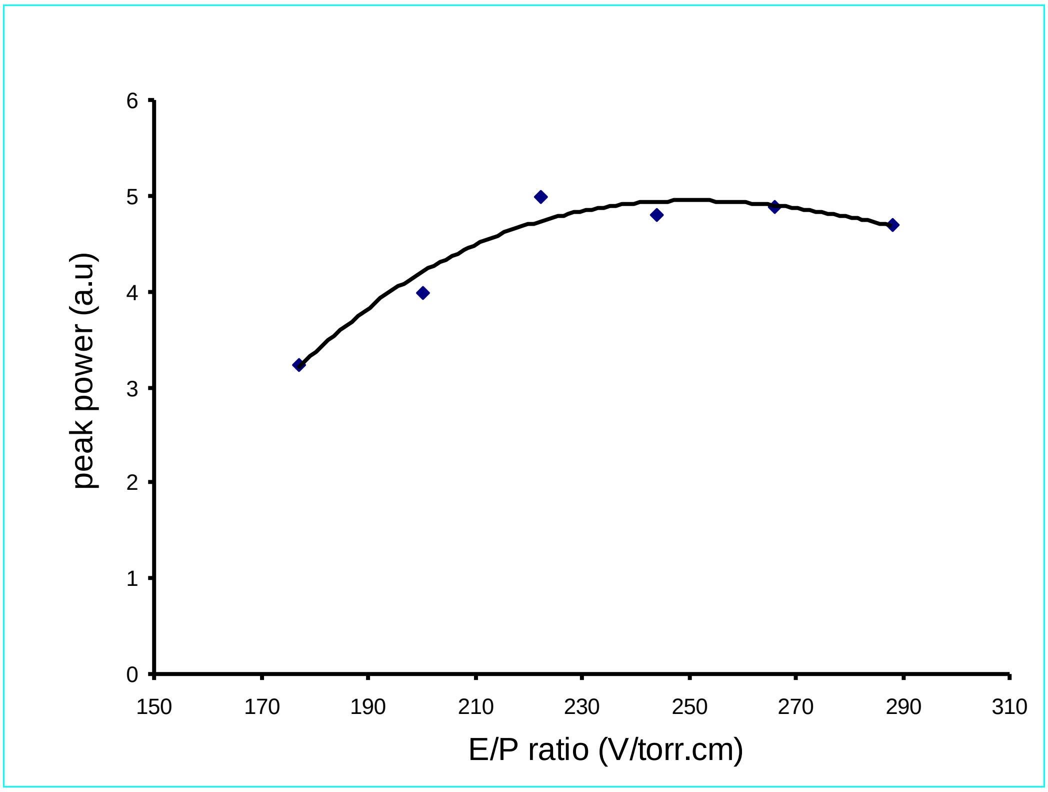

Fig. (11): The variation of peak power as a function E/P ratio at gas pressure constant (60 mbar).

Conclusions

One of the most important parts of the N_2 laser system is the shape of the electrodes. The V-shape electrodes is a good choice because of the high current density produced inside the laser channel can be acted as preionization then fast rise time of voltage and current pulse. The discharge parameters have been studied experimentally and concluded that: The peak laser power increases with applied voltage until reach certain value, the output will decrease. There is an optimum value of gas pressure gives the maximum peak laser power. The optimum value of the E/P ratio has been measured by determining the maximum value of peak laser power, and then dropping vertically on the X-axis. The output laser takes a somewhat saturated value when the capacitance of storage–side capacitor C_1 is in excess of that of switch –side capacitor $C_{2;}$ ($C_2 \leq C_1$). The output laser decreases when the capacitance of switch –side capacitor C_2 in excess that of storage –side capacitor C_1; ($C2 \geq C_1$). Provided that $C_1 = C_2 = C_o$, although the laser output increase with C_o.

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بناء منظومة ليزر النتروجين باقطاب على شكل حرف V

الخلاصة

تم بناء وتشغيل منظومة الليزر محليا للحصول على نبضة ليزر ضمن المنطقة الفوق بنفسجية وبطول موجي 337.1 نانو متر. ستوصف كل تفاصيل المنظومة من قناة الليزر القصيرة, منظومة الضغط الواطيء وتصميم اقطاب التفريغ الكهربائي على شكل حرف V. قمنا بدراسة عدة معلمات للتفريغ الكهربائي مثل ضغط الغاز داخل حجرة الليزر, الفولتية المسلطة على المتسعات و سعة متسعات البلوم لاين ومدى تأثيرها على قدرة الخرج الليزري. إن أفضل النتائج التي تم الحصول عليها كانت عند فولتية التشغيل 10 كيلو فولت, ضغط الغاز 60 ملي بار, مسافة بين الأقطاب 1 سم, معدل تكرارية 1 نبضة لكل ثانية بدون معدل جريان للغاز ونسبة ال E/P هي 222 فولت / (سم. تور).