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TE-N_2 Laser by Using Low Inductance Capacitor

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Abstract

The design, construction and operation of a transversely excited N_2 laser using low inductance capacitors, is presented, the laser pulse generation is 1200μJ with pulse width 8ns when operated at about 30mbar with applied voltage of 15-30 kV. The system is capable of giving 150 kW peak power. The best values of specific energy and breakdown voltage are 0.03 J/L and 600 V/cm-mbar respectively.

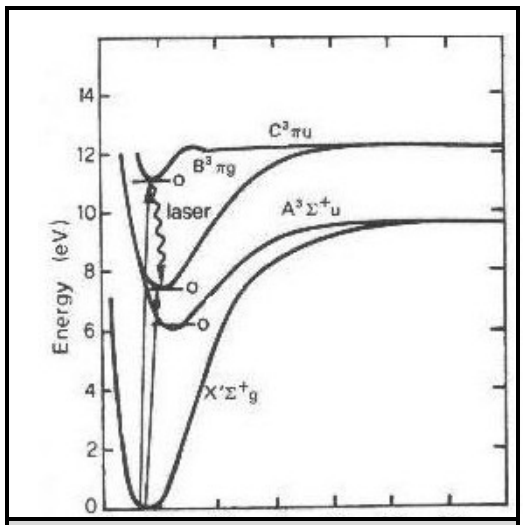
Keywords:Lasers,

1. Introduction

As a particularly relevant example of vibronic laser we will consider the N_2 laser. This laser has its most important oscillation at λ=337 nm (UV), and belongs to the category of self – terminating lasers.

The pulsed nitrogen laser is commonly used as a pump for dye lasers. The relevant energy level scheme for the N_2 molecule is shown in figure (1). Laser action takes place in the so-called second positive system i.e., in the transition from C $^3\pi_u$ state (C state) to the B $^3\pi_g$ state (B state) [1].

The excitation of the C state is believed to arise from electron – impact collision with ground state N_2 molecules. Since both C and B states are triplet states, transitions from the ground state are spin forbidden. On the basis of the Franck-Condon principle, we can however, expect that the excitation cross section to the =0 level of the C state will be larger than that the =0 level of the B state. Compared to the ground state ,the potential minimum of the B state is in fact shifted to larger inter nuclear separation than that of C state the lifetime (radiative) of the C state is 40 ns, while the lifetime of the B state is 10 s . Clearly the laser can not operate CW since condition ($\tau_1<\tau_{21}$) is not satisfied. It can however be excited on a pulsed basis provided the electrical pulse is appreciably shorter than 40 ns [2,3].



Fig(1) Energy levels of the N_2 molecule . For simplicity only the lowest vibrational level (υ=0) is shown for each electronic state [2].

Laser action takes place predominantly on several rotational lines of
υ"(0) ⟶ υ'(0) transition (λ=337.1nm). Besides being favored by the pumping process, as already

mentioned, this transition in fact exhibits the largest Frank – Condon factor.

A possible configuration for a N_2 laser is shown schematically in figure (2.a). Duo to the high value of electric field required (10 kV / cm at the typical operating pressure p=30 torr), a TE laser configuration is normally used. A fast discharge pulse (a few nanoseconds) is needed and a discharge circuit which achieves this, the so–called Blumlein configuration is shown in figure (2). The transmission – line angle of this circuit is shown in figure (2.b) , where Z is the impedance of the discharge channel and Z_0 is the characteristic impedance of the line – if the line is initially charged to a voltage V, and if $Z=2Z_0$, it can be shown that ,upon closing the switch , a voltage pulse of value V/2 and duration 2L/c is produced a cross Z (c is the e.m propagation velocity in the line) . By making L short enough, the system of figure (2.a) can produce a short voltage pulse suitable for driving the N_2 laser.

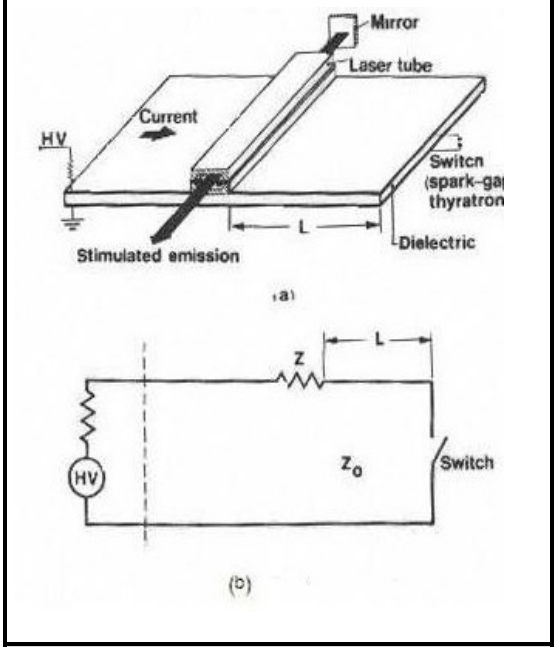


Fig (2) (a) Blumlein pulse generator using a flat transmission line. The discharge channel may typically be 2x0.5cm, the large dimension being along the discharge direction. (b) Transmission line analog of the Blumlein generator above[2].

Due to the high gain of this self-terminating transition, oscillation takes place in the from of amplified spontaneous emission .Thus the laser can be operated without mirrors. Usually, a single mirror is placed at one end of the cavity, since this reduces the threshold power, see equations (1,2) , and also provides a unidirectional output.

$$(\ln G)^{1/2} / G = \Omega / 4 \qquad (1)$$

$$(\ln G^2)^{1/2} / G^2 = \Omega' / 4 \qquad (2)$$

Where:

G is the gain of the active material

$\Omega = \pi D^2 n^2 / 4 \ell^2$ is the solid angle if no mirrors are used

$\Omega' = \pi D^2 n^2 / 16 \ell^2$ is the solid angle with one end mirror ,D is the diameter ,

ℓ is the length , and n is refractive index of the active material . The beam divergence of the N_2 laser without and with one end mirror are shown in figure(3).

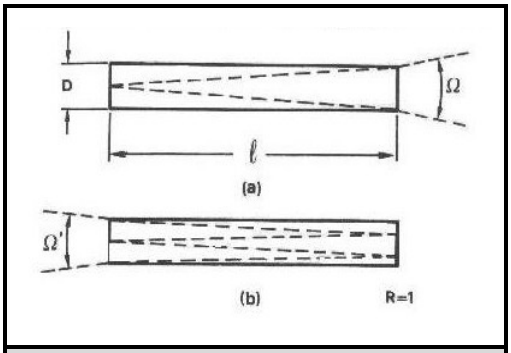


Fig. (3) Solid angle of emission in the case of amplified spontaneous emission: (a) active material without any end mirror: (b) active material with one end mirror[2].

2. Experimental

A Perspex block measuring (90x20x6) cm^3 machined by milling along 70 cm of its length and through its entire height to from rectangular laser channel. The N_2 admitted to the channel through the side walls by drilling 2 mm holes distributed uniformly in three rows along the lateral sides of the Perspex block .

The channel is sealed by two Aluminum covers from top and bottom, being 1.5 cm thick and extending 10 cm outside the Perspex block from both side, to support the damping capacitors as well as holding the electrodes.

The upper and lower covers are secured to the Perspex block by 20 thread inserts and proper blots. The upper cover has provision for 22 hand made spark plugs consisting of 2 mm tungsten pins insulated and fastened to the upper cover by external nuts. Another stainless steel plate is machined to hold the lower electrode such that another 22 stainless steel pins opposing to ones extending from the corresponding spark plugs, as shown in figure (4) .

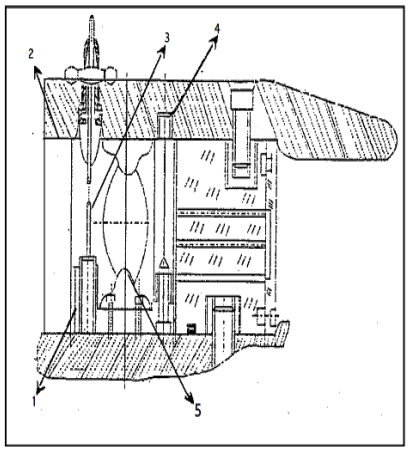


Fig. (4) Schematic of Laser Channel
1.St. St plate, 2.Al-Electrode holder
3.Preionizing Pin,4.Perspex Pillar,
5.Electrode

The electrodes are machined according to Chang profile [4] having dimensions of (2x2x60) cm^3 with spacing of 1.8 cm between them and 2mm gap between the preionization pins . The active discharge volume is (60x1.8x3) cm^3. Finally the channel is terminated with two quartz windows 5 cm in diameter and 4 mm think. 10 Perspex pillars are used to connect the lower stainless steel plate to the upper Aluminum electrode holder, such that a proper parallelism of the electrodes can be obtained along their entire length, through adjustments of the screws used to fasten the Perspex pills to the upper and lower plates. A 2mm gap is left between the spark plugs and the stainless steel pins, which is adjusted carefully to insure good spacing and alignment for all pins.

3. Results

A charge transfer excitation with automatic preionization has been used throughout the work, using a triggered spark gap [4-7]. The details of the electric circuit used are shown in figure (5)

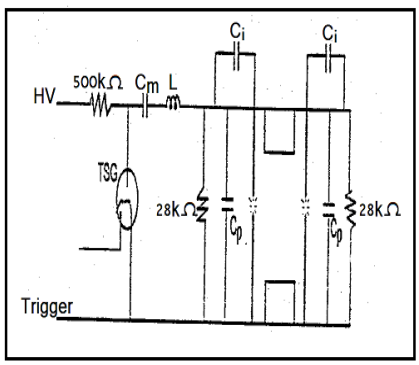


Fig.(5) Electrical Excitation Circuit with Preioniziation

Different operating values of the main peaking capacitors, and the way the preionization capacitors are distributed along transfer and better along the spark plugs have been widely investigated to achieve a fast charge transfer and better energy output per pulse. These values are as follows.

Main capacitor C_m =66.6 nF
Peaking capacitor C_p = 24.0. nF
Preionization capacitor C_i = 2.2 nF

The optical resonator consists of a flat Al mirror placed externally at the end of the laser channel, and front quartz window. The dependence of the output energy, the charging voltage and pressure in side the channel, is shown in figure (6) and figure (7) where it can be noticed that a linear relation between output energy and applied voltage, but the leak of power supply to give voltage higher than (30-32) kV limits the voltage, where it seems possible to get higher output for higher voltages. The relation between the output energy and operating pressure was around 30 mbar.

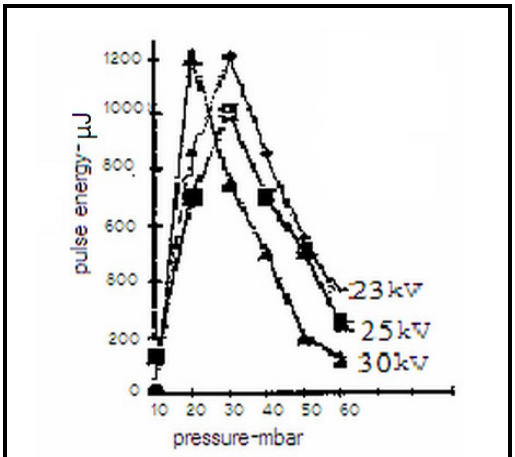


Fig.(6) Pulse dependence on pressure for different applied voltage

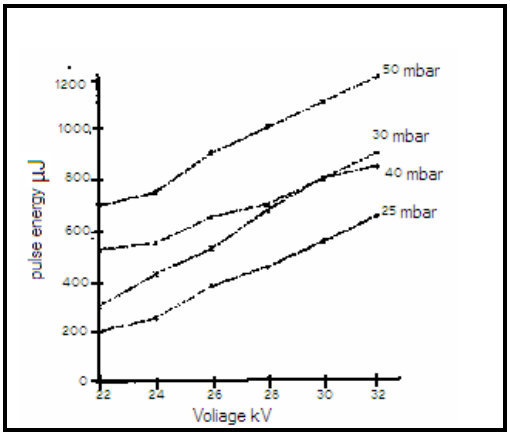


Fig.(7) Pulse Energy Dependence on Applied voltage for Different Pressures

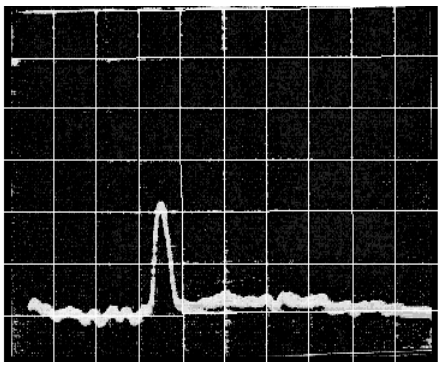


Fig. (8): Time behavior of the output laser pulse X-axis 10 ns/div, Y-axis 10 kV /div

The time behavior of the laser pulse is shown in figure (8) using a Korad and Hammatsu photo cathodes detector (with calibration 10.2kV~600µJ) with an Iwatsu TS8123 oscilloscope respectively

4. Discussion & Conclusion

A maximum output energy (1200µJ) was achieved, in cases where the discharge was free of arcs and homogenously distributed the laser channel, but the output deteriorated drastically when the discharged trued to arcs and streamers. Therefore the preionization scheme plays an important role in the performance of laser and hence, careful attention should be given to the location and distance setting of the preionization pins with respect to spark plug. And the parallelism of the main electrodes. Higher output may be achieved by trying further combinations of the main peaking capacitors, used to store and dump the energy in the gas. It may be useful also to enlarge the discharge volume through the increase of the lateral dimension of the electrodes to flatten the region responsible for uniform discharge.

- Even thought, the system was operated under flow conditions and single shot, it was possible to the repetition rate up 5Hz with a declination of
- t he output to 25% of its maximum value. Therefore it may be necessary to study the effect of the gas
- flow and the repetition rate upon the output energy.

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ليزر النيتروجين ذو التهيج المستعرض باستخدام مكثفات الحث الواطئ

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الخلاصة :

تم تصمم وبناء وتشغيل ليزر النايتروجين ذو التهيج المستعرض بأستخدام دوائر قليلة الحثية ، حيث يولد نبضة ليزر بحدود 1200 مايكرو جول وعرض نبضه 8 نانوثانية عند ضغط 30 ملي بار وفولتية بحدود (30-15) كيلو فولت بحيث تستطيع توليد قدرة عظمى بحـــدود 150 كيلو واط . وكانت احسن قيم للطاقة النوعية وفولتية الانهيار هي (0.03) جـــــول / لتر و (600) فولت / سم ملي بار على التوالي .