Carta *Revista Mexicana de Física* **37** *No. 3 (1991) 391–395*

High efficient nitrogen laser

V.J. Pinto*, V. Aboites and J. de la Rosa**

Laboratorio de Láseres, Centro de Investigaciones en Optica
Apartado postal 948, León, Guanajuato, 37000 México

(Recibido el 26 de noviembre de 1990; aceptado el 14 de mayo de 1991)

Abstract. This paper reports a N_2 transversal laser which is excited by discharging a pulse generator with a 2 to 4 nF capacitance and a 10 to 16 KV voltage. This discharge tube with a coaxial 500 pF peaking capacitor is 30 cm long. A maximal laser energy of 0.5 mJ with an efficiency of 0.11% was obtained.

PACS: 42.55.–f; 42.55.Em; 42.60.By

1. Introduction

Nitrogen lasers have been investigated since the sixties. Such lasers deliver short pulses (50 ps to 20 ns) at a wavelenght of 337.1 nm and they are excited by high voltage nanoseconds pulses (< 50 ns) [1]. The Blumlein circuit is since 1967 [2] for this purpose widely used. It has been reported output energies with this circuit up to 7 mJ and 0.07% efficiencies [3,4,5]. Using a circuit with discrete capacitors parallel to the discharge electrodes has been rised the output energy up to 20 mJ without efficiency increase [4]. In Mexico, Blumline circuit N_2 lasers have been build since the eighties [9], however no attempt was done to increase their efficiency. Santos *et al.* [6] proposed recently to use a coaxial concentric capacitor to the optical axis and conected in parallel to the discharge electrode. They reported output energies up to 2.2 mJ with a higher efficiency of 3% which is similar to the efficiency from comercially excimer lasers [7]. In this paper it is reported the operation of a Nitrogen laser similar to the arrangement of Santos *et al.* [6], using national technology. A maximal laser energy of 0.5 mJ was obtained with a 0.11% efficiency.

2. Experimental arrangement

The experimental arrangement is shown in Fig. 1. The low inductance 4 nF capacitor C_1 is charged to V_0 through R and L. Then it is discharged across the laser tube using an atmospheric-pressure spark gap as a fast switch. The breakdown voltage V_Z of the spark gap is regulated by varing the electrode distance. The supply voltage V_0 is applied to the spark gap with the coil L, which after spark gap switching

*Permanent Address: Physics Department, University of Essex, England CO4.
**Permanent Address: ESIME-IPN, 07738 México, D.F.

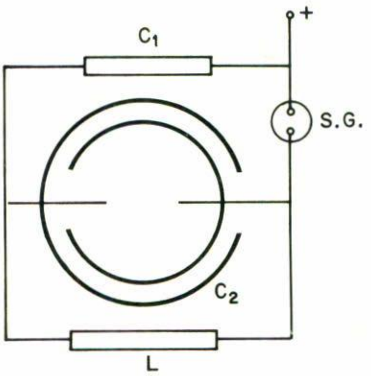

FIGURE 1. Schematic diagram showing the layout of the experiment.

should have a higher impedance than the laser discharge, so that the charge from C_1 flows mainly through the laser tube but not through L. The charge from C_1 would be transferred to C_2 and the discharge electrode at the laser tube until the laser discharge takes place. At the same time stored charge in C_2 and C_1 will be delivered in the laser plasma. As consequence of the low inductivity of the loop C_2 added to the discharge zone, the current pulse in the discharge of this Polloni circuit is faster than in a conventional Blumline discharge circuit arrangement [8]. As it is known [10], the rise time T of the current pulse of a discharge capacitor C depends on its inductance L as $T \propto \sqrt{LC}$ therefore, due to the lower inductance of the circuit components of a Polloni discharge circuit, this will be able to produce shorter discharge pulses than a Blumline discharge circuit. As it is explained later on, this fact is very important to understand the higher efficiency of a Polloni-type laser.

The discharge tube is shown in Fig. 2, discharge lenght is 30 cm and due to the lack of Rogowsky type electrodes these were built with 0.5 inch hexagonal Brass bars. C_2 was built using 0.1 mm Mylar foil as dielectric having a capacitance of 0.5 nF. The laser tube is closed at both ends with Quarz Brewster windows. The Nitrogen flows axialy continuosly through the tube. The optic is a 100% reflecting mirror without outcoupling mirror. The laser output energy was measured with a Molectron JD-100 energy meter. The pulse duration was monitored with a Motorola MRD-500 PIN diode and a 300 MHz Tektronix oscilloscope.

3. Results

Fig. 3 shows the laser pulse energy against gas pressure for different gas flows, $V_0 = 15$ KV and $C_1 = 4$ nF. A maximal efficiency of 1.1×10^{-3} for 386 hPa (1 hPa = 1 mbar) pressure is obtained. The high efficiency observed can be explained by the characteristics of the excitation electric circuit used. As already explained due to the cilindric coaxial geometry used, the Polloni circuit used has a lower inductance

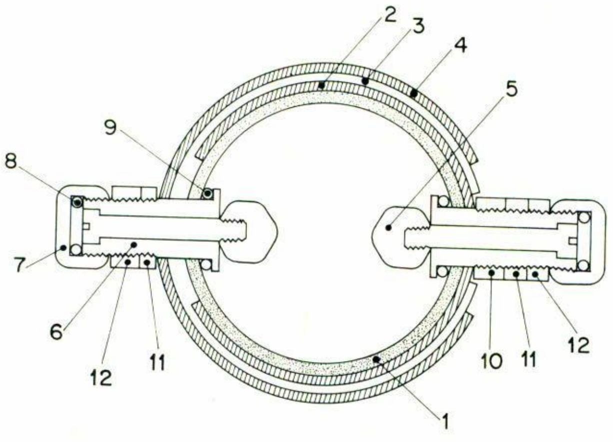

FIGURE 2. Transversal section of the laser (1. PVC, 2. Aluminum, 3. Mylar, 4. Aluminium, 5. Brass —electrodes—, 6. and 7. Brass, 8. and 9. O-Ring, 10., 11. and 12. Brass).

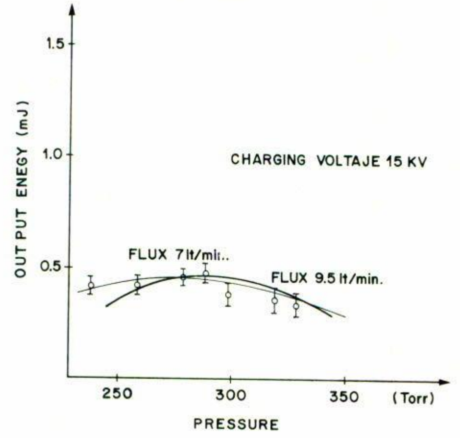

FIGURE 3. Laser pulse energy versus gas pressure for different gas flows. The solid points and the thiner line show the 7 lt/min flux plot.

than commonly used Blumline excitation circuits. Therefore the lower inductance of our circuit allows a short rise time electric pulse which account for the higher efficiency. This is so because in a N_2 laser, molecules remain excited only a short time of about 40 nsec, therefore with a Blumline discharge excitation circuit (which produces long pulses) many excited N_2 molecules will return to the base state before the electric excitation pulse reached its maximun, whereas using a Polloni discharge excitation circuit (which produces shorter pulses) this will not happen, increasing the total efficiency of the laser. Fig. 4 shows the laser pulse energy against the gas

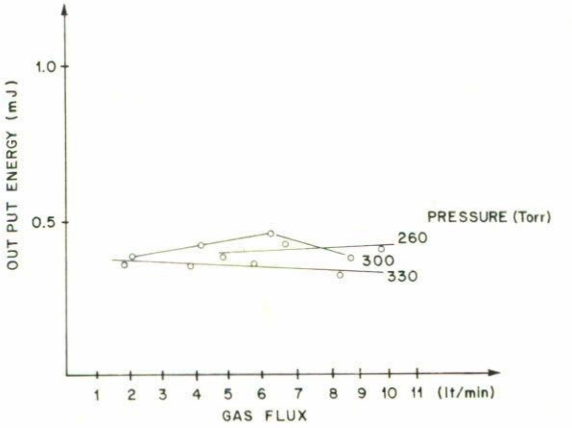

FIGURE 4. Laser pulse energy versus gas flow for different pressures.

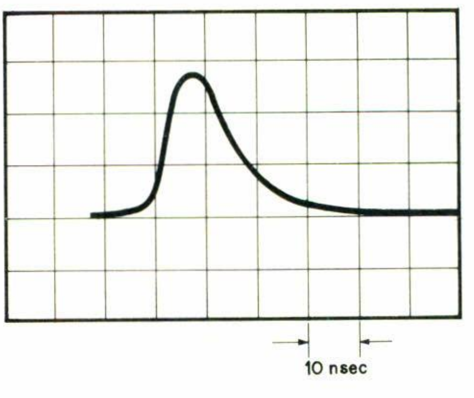

FIGURE 5. Temporal behaviour of a laser pulse with 10 nsec FWHM.

flow for different pressures. Fig. 5 shows the temporal behaviour of the laser pulse with a 10 nsec FWHM duration.

4. Conclusions

The experimental results show a higher efficiency (0.11%) than the obtained with conventional circuits (usually $< 0.07\%$) despite the laser is operated without outcoupling mirror. A higher laser pulse energy is expected for an optimal outcoupling mirror. A detailed research of the temporal behaviour of the current and voltage at the electrode will be useful in order to understand the circuit operation and will give criteria for the choice of the optimal value of C_2.

References

1. M. Geller, D.E. Altman, and T.A. DeTemple, *Appl. Opt.* **7** (1968) 2232.
2. J.D. Sipman Jr., *Appl. Phys. Lett.* **10** (1967) 3.
3. I. Nagata and Y. Kimura, *Phys. E: Scien. Inst.* **6** (1973) 1193.
4. D.L. Franzaer, *et al.*, *IEEE, J. Quant. Electr.* **QE-14** (1978) 402.
5. E. Armandillo and A.J. Kearsley, *Appl. Phys. Lett.* **41** (1982) 611.
6. D.O. Santos *et al.*, *Appl. Phys.* **B41** (1986) 241.
7. H. Pummer *et al.*, *Laser und Optoelektronik* **2** (1985) 41.
8. J. de la Rosa, E. Gonzaga and J. Arreazola, published in Proc. of "Coloquio Académico ESIME", Nov. 1989.
9. S. Godoy, A. Porta, *Instr. y Des.* **1** (1982) 3.
10. F.B.A. Früngel, *High Speed Pulse Technology,* **1**, Academic Press (1965) p. 184.

Resumen. Se reporta un láser transversal de N_2 que es excitado con un generador de pulsos con capacitancia de 2 a 4 nF y voltajes de 10 a 16 kV. El tubo de descarga contiene un capacitor coaxial de 500 pF y 30 cm de longitud. Se obtuvo energía láser máxima de 0.5 mJ con eficiencia de 0.11%.