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A New Simple Model for High-Power Pulsed Gas Lasers*

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Abstract. An analysis of a modified electrode geometry for pulsed gas-laser excitation circuits, generating shorter excitation pulses than those normally obtained, is reported. Results from an atmospheric N_2 laser obtained with this electrode geometry are compared with others available in the literature.

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The behaviour of an N_2 laser with a particular electrode design has recently been published [1]. This laser had a conventional excitation circuit similar to that of Fig. 1, with an extra negative plate located in the upper part of the circuit, as shown in [2].
The different electrode design gave high peak-power output emission values (1.6×10^6 W vs. 0.8×10^6 W for the same laser with conventional electrodes) shifting the N_2 pressure for maximum laser emission from 350 Torr to 1 atm. Figure 2 presents both electrode designs and laser output behaviour as a function of N_2 pressure.
In order to analyze this result, models similar to a part of the laser circuit were constructed (Fig. 3) without any change in both physical dimensions and materials, when compared with the laser. Figure 3a and b correspond to conventional and modified electrode geometries, respectively. Point A corresponds to the edge of the electrode where the discharge takes place. On that point an FWHM 8×10^{-9} s width, 10 V peak voltage pulse was applied, generated by an HP 8012 B pulse generator. On the same point A, the resulting signal (generated through the normal waveguide pulse propagation process) was analyzed with a 7904 Tektronix oscilloscope and a P 6057 Tektronix probe.
Results obtained from these analysis were clearly different, as is easily seen in Fig. 4a and b. Several dips appeared in Fig. 4b which are not detected in Fig. 4a. Taking the whole pulse as the superposition of multiple reflections of the original pulse propagating in the waveguide, the first part with its correspondant dip was isolated and analyzed in frequency by the Fast Fourier Transform method (FFT). The result was the detection of an absorption region around 550 MHz for the analysis of Fig. 4b, not present in the Fig. 4a case. This frequency region almost coincides with the theoretical fundamental frequency region (530 MHz)

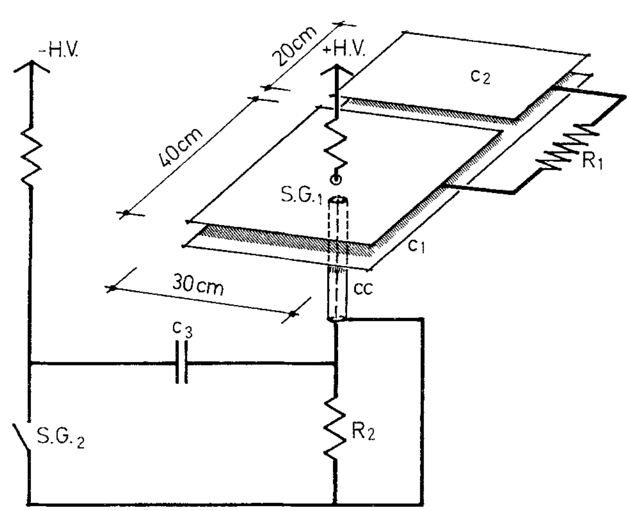

Fig. 1. Laser excitation circuit (+HV: high-voltage, $C_1 = C_2$: capacitors, SG_2: trigger spark gap, SG_1: main spark gap, CC: coaxial cable

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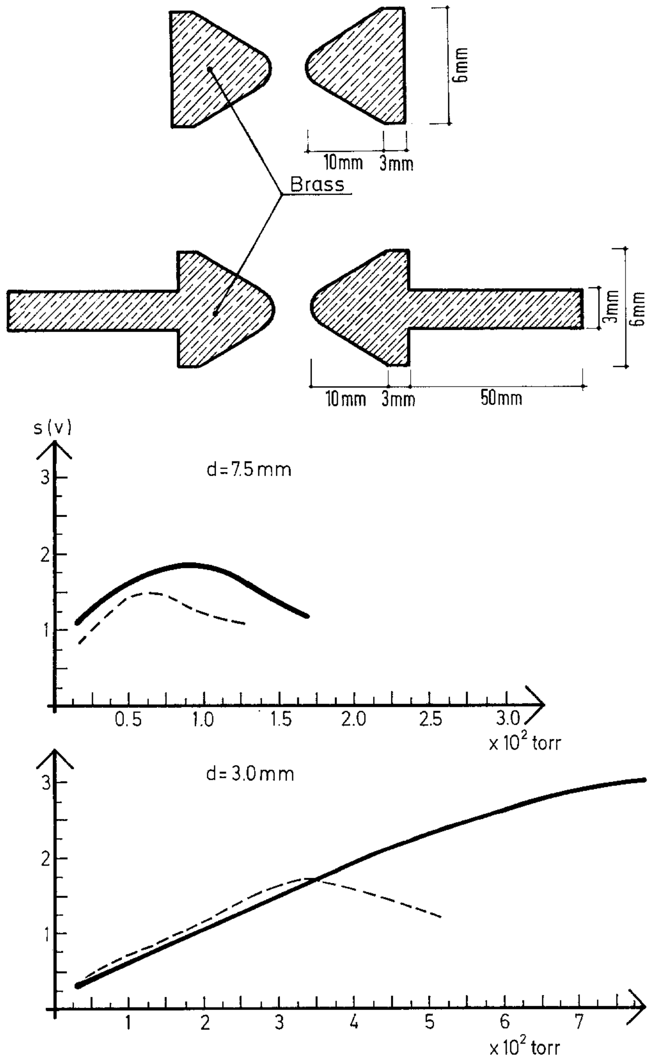

Fig. 2. (a) Conventional and modified electrode geometries. (b) N_2 power output (in arbitrary units) as a function of pressure for two different interelectrodic distances, with conventional electrode geometry (- - -) and modified electrode geometry (——). (d: interelectrodic distance

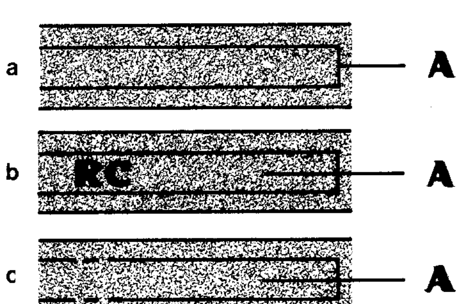

Fig. 3. (a) Testing model for the conventional electrode geometry case. (b) Testing model for the modified electrode geometry case, being the open resonant cavity labeled by *RC* (c) Testing model for the modified electrode geometry case plus antennas for a better coupling between the waveguide and *RC* (▒ dielectric, —— copper plate)

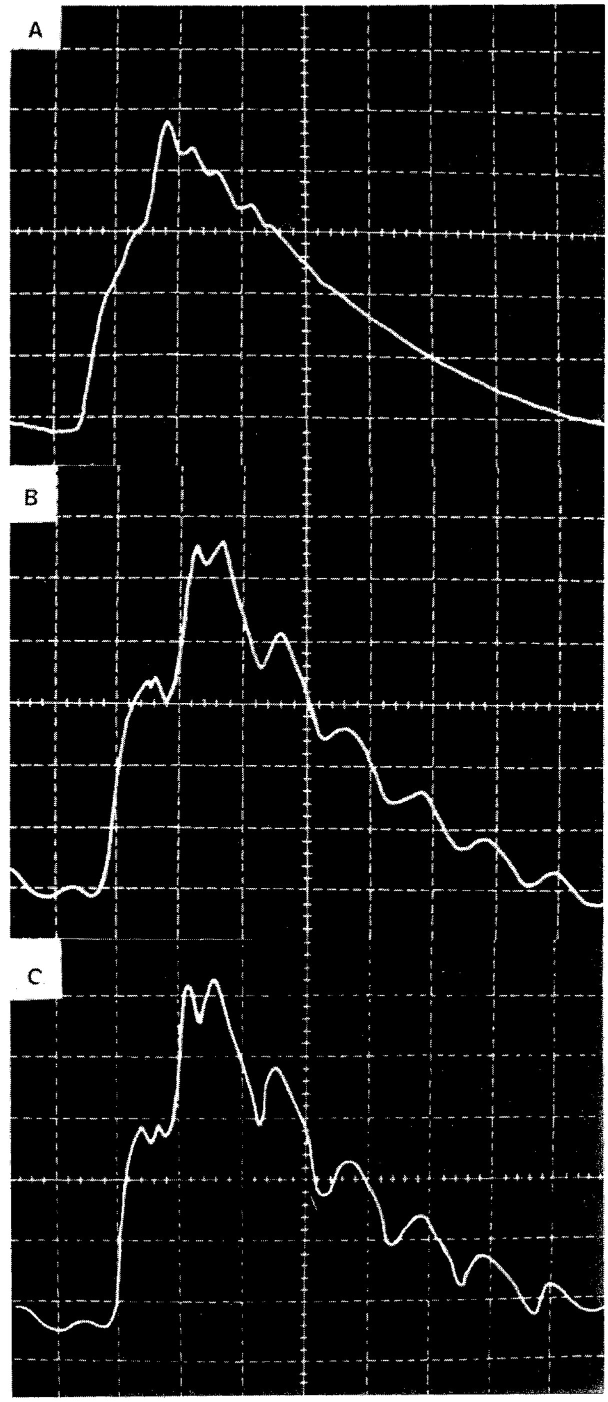

Fig. 4. Propagation of an 8×10^{-9} s width, 10 V pulse through models of Fig. 3a–c, respectively. Time base: 10 ns/cm; Vertical scale: 0.5 V/cm

of the open resonant cavity labeled *RC* in the design. *RC* is determined by the inner plates (positive) of the waveguide and the rear of the electrode.

It is then suggested that a coupling exists between the waveguide and the resonant cavity. This coupling together with the adjustment of the *RC* fundamental resonant frequency in order to match the corresponding value of the original pulse, generated by the spark gap plus waveguide system alone, would give a higher-frequency excitation pulse result.

In order to apply these results, a new excitation circuit (Fig. 5) was constructed, with some modifications when compared with that of Fig. 1. Not only the double waveguide system was completed on both lateral sides in order to avoid electric leaks by the corona effect (Fig. 5b and c) but the open end of the circuit was isolated with epoxi-resin, as shown in Fig. 5a (looking for a better coupling between *RC* and the waveguide, in order to obtain results similar to that of Fig. 4b). Table 1 gives characteristics of the laser emission generated with that model.

Peak-power laser output values were measured with an EGG SGD 040 photodiode (calibrated in power against a commercial N_2 laser), a set of neutral filters and a 7904 Tektronix oscilloscope. Energy measurements were made with a Scientech 37-0002 mirror disk calorimeter. Because of the low energy per pulse value, a group of five measurements having, each, 10^4 pulses was made, being the mean energy per pulse obtained in that way. Pulse width values were then deduced from both power and energy measurements.

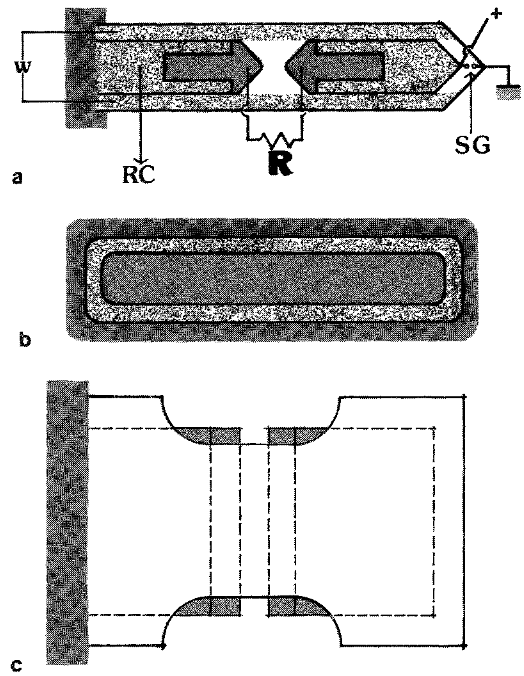

Fig. 5. (a) Side view of a modified N_2 laser excitation circuit, showing the open resonant cavity (*RC*), the epoxi-resin on one end of the laser system (shaded) and waveguides (w). (b) End view. (c) Upper view

Table 1. Characteristics and results of present circuits models with results of some other N_2 lasers

	Charging voltage [kV]	Inter-electrodic distance [mm]	Length of the discharge channel [cm]	Laser peak power output [MW]	Laser pulse width	N_2 pressure [atm]
Ref. [3]	40	5	60	1.5	< 1 ns	1
[4]	25	4	50	1.0	400 ps	1
[5]	25	5	25	1.0	1 ns	1
[6]	40	3	25	> 1.0	< 1 ns	1
[7]	20	1	50	> 1.0	50 ps	6
Present Work						
Without resonant cavity (Fig. 1)	18	3	30	1.5	300 ps	1
With resonant cavity (Fig. 5)	18	4	30	3.9	82 ps	1
With resonant cavity plus enhanced coupling (Fig. 6)	18	4.8	30	6.0	53 ps	1

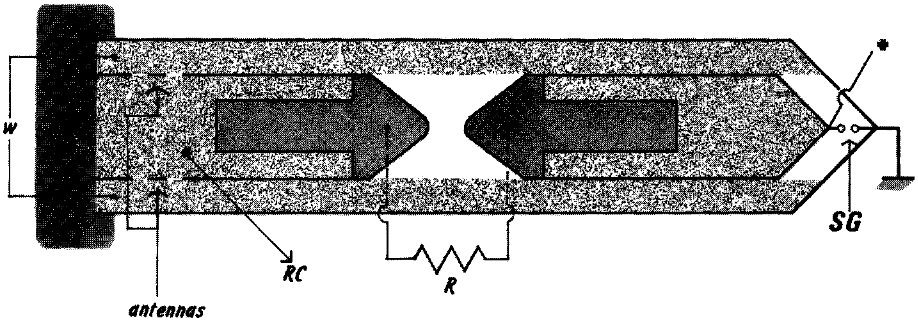

Fig. 6. Final N_2 laser excitation circuit diagram showing, besides facts mentioned on Fig. 5, antennas for a better coupling between waveguides (w) and the resonant cavity (*RC*)

dielectric — "Epoxi" — copper plate — Brass

Because of the low pulse width value obtained (when compared with reported values of [3–7]), by adding an *RC* to a normal waveguide excitation system, a better coupling between the waveguide and *RC* was developed by placing several antennas linking both regions. Then, the *RC* importance was expected to be stressed. Figure 6 shows the final laser circuit developed, Fig. 3c being the scheme of the corresponding testing model and Fig. 4c its propagation result.

More pronounced dips were now observed when compared with the result of Fig. 4b, implying a more efficient frequency filtering of the excitation pulse.

Table 1 shows, for the Fig. 6 case, a 53×10^{-12} s laser pulse width value, an extremely low one for this kind of laser (particularly when compared with previously reported values under the same N_2 pressure condition).

It is necessary to point out that for all the set of tested lasers an angular electrode adjustment was made in order to obtain a maximum peak power output from one end of the discharge region when compared with the other (an 80 : 1 value, typically).

Then, it is suggested that the adjustment of the open resonant cavity dimensions to have its fundamental resonant frequency in the region where the unperturbed excitation pulse has its maximum weight, modifies excitation pulse characteristics. The resonant cavity transforms the original pulse in another of higher frequency, giving a more efficient N_2 excitation. This proposal is based on the results obtained when a better coupling between the waveguide and the resonant cavity was established.

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