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PULSED GAS LASER IONIZATION BY AN ALPHA PARTICLE BEAM

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ABSTRACT

In this work, an α particle beam generated by radioactive sources is used as a suplementar method of pre-ionization in a N_2 laser. Effects of α radiation are compared with those produced by varying the distance between the electrodes and/or the electrode profile (corona effect intensity).

1.INTRODUCTION

New methods for optimizing pre-ionization in pulsed gas lasers are a very chalenging task. The search of stimulated emission pulses [illegible]ing reduced pulsed width values [illegible]es special care regarding initial conditions of active gas media, i.e., how to obtain in an almost instantaneous way, a very low impedance value. Ionization methods like pin arrangment [1], DC [2] or pulsed [3] wire systems, corona blade electrodes [4], UV ligth [5], etc., have been investigated. It is necessary to point out that all of them require some energy that has to be taken into account in laser efficiency calculations.

This extra energy consumption does not exist if emission from radioactive sources is used for pre ionization. Experiments in CO_2 lasers involving radioactive sources with emission of γ rays [6] or α particles [7] have shown the feasibility of this method.

In this paper we report the ionization effects of α particles emitted from Americium sources (^{241} Am), on the characteristics of N_2 337.1 nm stimulated emission wavelength and the corresponding high voltage excitation pulse.

The characteristic energy of α particles is about 5.3 MeV, and then its ionizing power per unit path length is three or four orders of magnitude higher than that of the 0.1 - 0.2 MeV electrons custumarily used in ionizing N_2 lasers [7].

2. EXPERIMENTAL SET - UP

The laser employed in this experiment was described in detail before [8] and its schematic layout is presented in Figure 1-a. The discharge tube is 30 cm long, the transmission line (C') has a capacitance of 6.0 nF and the storage capacitor (C) is 9.8 nF. This system works at 37.5 torr and 75.0 torr pressure values, being C charged at 5.7 kV and 11 kV, respectively. Under these conditions, and neglecting electrode profile and/or interelectrodic distance value effects, the voltage/pressure ratio is maintained constant at 152 volts/torr.

Two different electrode profiles are used, as it is shown in Figure 1-b. For the one generating the most pronounced corona effect, the interelectrodic distance d is 3.0, 4.0 and 5.0 mm while for the other pair of electrodes d is 3.0, 4.0, 5.0, 6.0, 7.0 and 8.5 mm. Then, keeping the V/p ratio constant, the reduced electric field (E/p) takes different values by modifying the interelectrodic distance and/or the corona effect intensity according to the different electrode profiles.

The α particles are obtained from five ^{241}Am sources, each of them having an activity of 1.35 μCi. According to the number of allocated sources, it is possible to compose an activity of 1.35, 2.70, 4.05, 5.40 and 6.75 μCi on the laser discharge tube. The sources are located at a distance of 15 mm from the central discharge region, as shown in Figure 1-c.

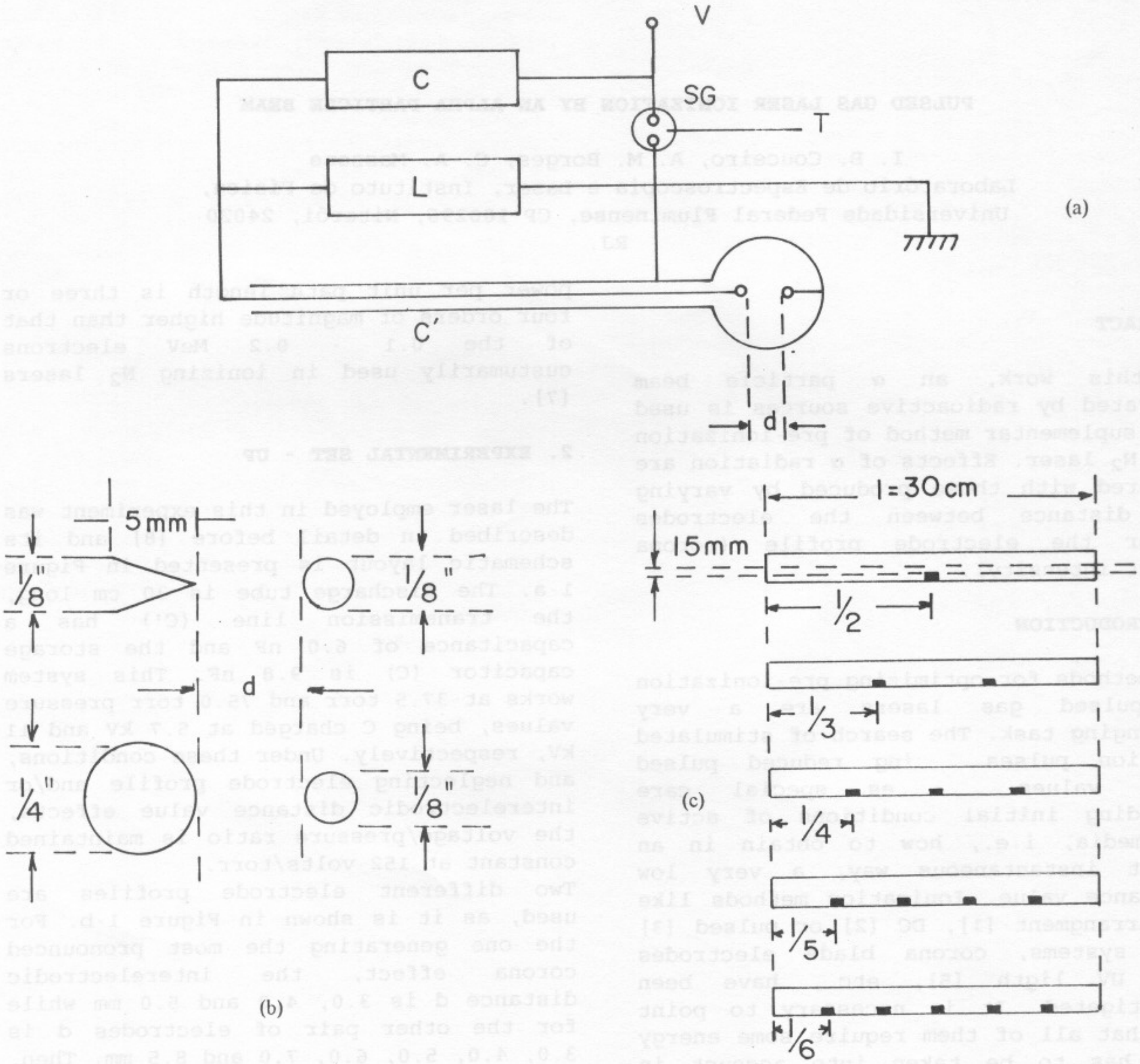

Figure 1-a. Excitation circuit being C (charging capacitor) = 9.8 nF, C'(transmission line) = 6.0 nF, L (inductance) = 10.7 μH, SG = Spark-gap, T = trigger, d = interelectrodic distance, V (charging voltage) = 5.7 kV (for 37.5 torr N_2 pressure) or 11.4 kV (for 75.0 torr N_2 pressure).

-b. Electrode geometries. Different profiles generate different corona effect intensities, for the same d value.

-c. Arrangment of ^{241}Am sources inside the laser discharge tube. In all cases the purpose was to obtain the maximum possible uniformity in α radiation distribution.

The laser radiation is detected with a ITL 1850 vacuum photodiode, a 7104 Tektronix oscilloscope and a DCS01 Tektronix digital converter. Voltage pulses are analyzed with a capacitance divider system and a P6015 Tektronix probe.

3. RESULTS AND DISCUSSION

The behaviour of the stimulated emission pulse width value (Δt_{laser}) of the 2^+ 0-0 band and that of the excitation voltage pulse period, as a function of the number of ^{241}Am sources allocated into the laser discharge tube, are shown in Figures 2,3. One can observe that both (Δt_{laser}) and the excitation pulse period decrease when the radioactive activity increases. This fact is connected with a gas impedance reduction to a value which optimizes the laser emission process.

Nevertheless, more important than the evidence of the α particle ionization effect is a comparison with others ionization effects acting on the laser system.

Therefore, we first analyze Δt_{laser} values and corresponding voltage pulse behaviour as a function of d and electrode profile values. Results are summarized in Figures 4,5. It is important to observe that Δt_{laser} exhibits monotonic decreasing values up to a minimum at which starts to increase. The voltage pulse period gives a minimum which is coincident with that of Δt_{laser}. The left side of Figures 4, 5 are coincident in the sense that a reduction in gas impedance means a better N_2 / N_2^+ gas ratio, being N_2 the number of neutral nitrogen molecules and N_2^+ the corresponding ionized ones. Then, we are optimizing both N_2 and N_2^+quantities, reduzing the number of neutral nitrogen molecules. The fact that the excitation voltage pulse period remains constant in the right side of both Figures 4 and 5 is in accordance with recent results [9], showing that we have reached the condition where gas impedance no more modifyes the original excitation pulse generated in the C + L + SG section of the laser circuit (see Figure 1-a). Then, for the right side of Figures 4 and 5, to reduce gas impedance value has no more importance because we can not obtain an excitation voltage voltage pulse period value lower than that generated in the electric circuit. This is a very important conclusion because the corresponding right side of the Δt_{laser} curve can not be then explained by impedance value modifications. Adding to this the 70 % peak power laser output reduction detected in the right side of Figures 4,5, we arrive at a point were the hypothesis of N_2 / N_2^+ ratio adjustment makes a reasonable sence.

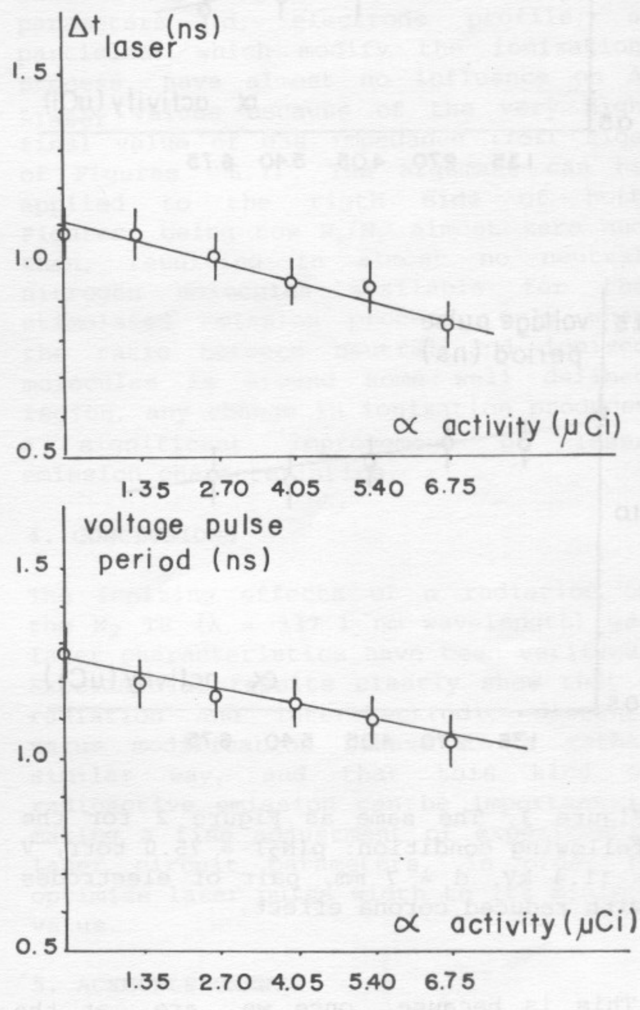

Figure 2. Δt_{laser} (upper trace) and excitation voltage period (lower trace) behaviours as a function of applied activity. Other parameters are $p(N_2)$ = 37.5 torr, V = 5.7 kV, d = 7.0 mm, pair of electrodes with lower corona effect.

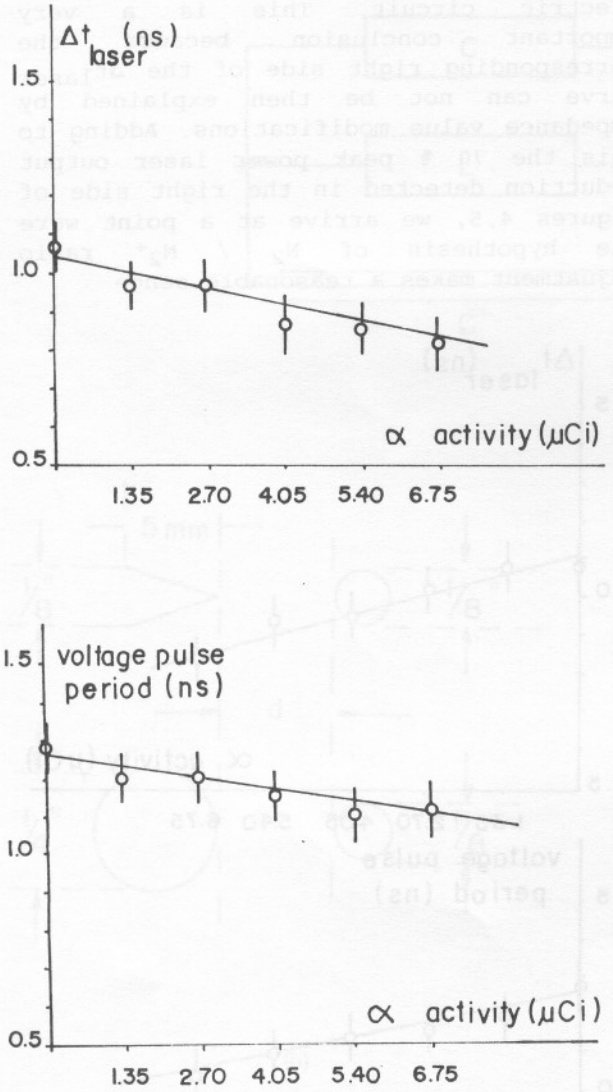

Figure 3. The same as Figure 2 for the following condition: $p(N_2)$ = 75.0 torr, V = 11.4 kV, d = 7 mm, pair of electrodes with reduced corona effect.

This is because once we are at the condition were Δt_{laser} is a minimum, an increase in the number of ionized molecules - by an increase of the ionization effects - no more helps the laser emission, only reducing the number of nitrogen molecules available for the amplification process below the optimum N_2 / N_2^+ ratio (being necessary to point out again that pressure value is constant in arriving to this result).

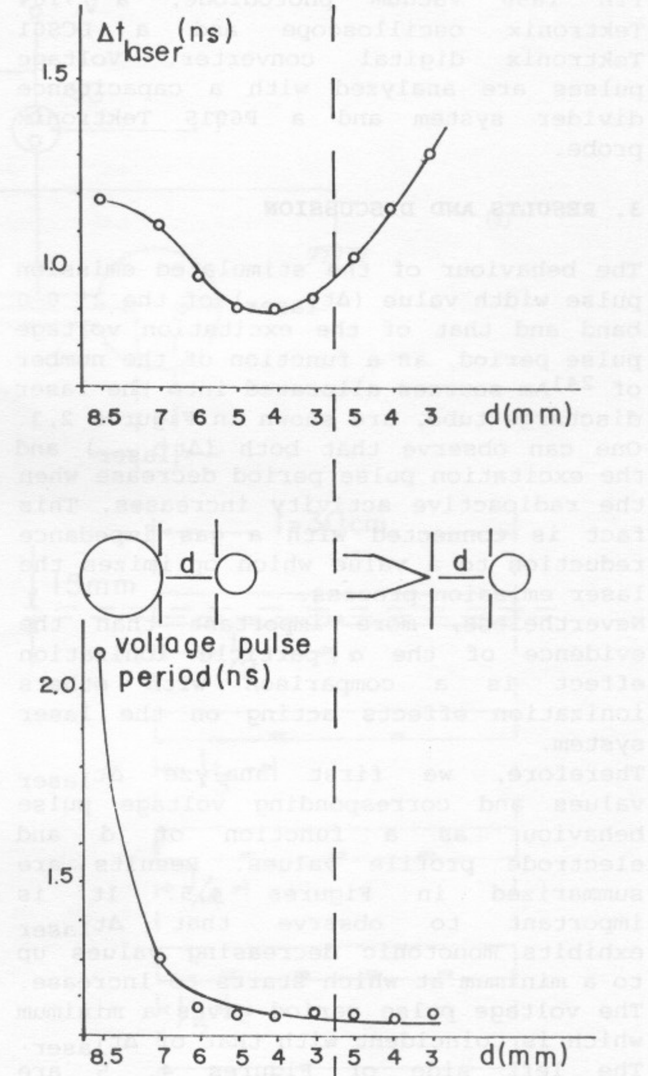

Figure 4. Δt_{laser} (upper trace) and excitation voltage period (lower trace) behaviours as a function of d and/or corona effect intensity. $p(N_2)$ = 37.5 torr, V = 5.7 kV.

Once we understand d and corona effect roles in the ionization process, Figures 6 and 7 now present the same results of Figures 4 and 5 were rectangular areas are showing detected modifications in the laser characteristics when one to five ^{241}Am sources are introduced into the laser discharge tube. We observe, taking into account our experimental

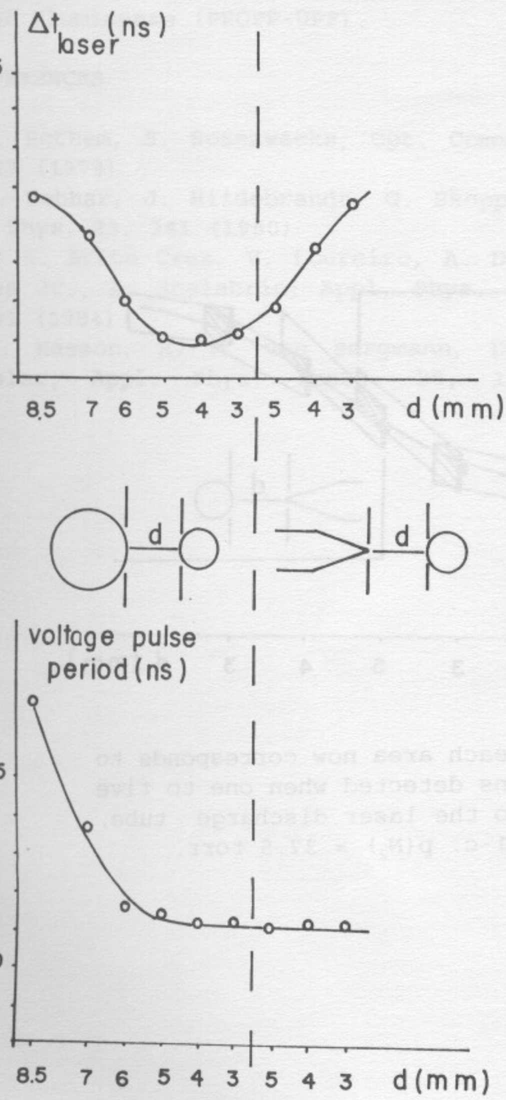

Figure 5. The same as Figure 4, for $p(N_2)$ = 75.0 torr, V = 11.4 kV

uncertainty, that an α activity value of 6.75 μCi leads to the same results obtained when the d value changes in 1.0 - 1.5 mm. Then, it can be stated that for this order of α activity (6.75 μCi), we are generating an small perturbation on the stimulated emission characteristics, when compared with those produced by interelectrodic distance modifications.
With the radioactive source available during the course of this work, we are obtaining significant results only in some particular situations. For example, with low corona effect pair of electrodes and a d value of 7.0 mm, an α activity variation from 0 to 6.75 μCi makes the Δt_{laser} value to change from 1.15 ns to 0.9 ns. This means a laser pulse width value modification of 21 %.
The fact that only in some special d plus electrode profile group of values (low corona effect pair of electrodes, 7.0 mm > d > 5.0 mm, see Figures 6,7) α particles show a significant influence on laser emission characteristics is directly connected with the physical behaviour of N_2 / N_2^+ ratio. Being this ratio very high, the all group of parameters (d, electrode profile, α particles) which modify the ionization process, have almost no influence on Δt_{laser} values because of the very high final value of gas impedance (left side of Figures 6,7). The argument can be applied to the rigth side of both Figures, being now N_2/N_2^+ almost zero and then, resulting in almost no neutral nitrogen molecules available for the stimulated emission process. Only when the ratio between neutral and ionized molecules is around some well defined region, any change in ionization produces a significant improvement on laser emission characteristics.

4. CONCLUSIONS

The ionizing effects of α radiation on the N_2 TE (λ = 337.1 nm wavelength) gas laser characteristics have been verifyed. Experimental results clearly show that α radiation and interelectrodic distance value modification behave in a rather similar way, and that this kind of radioactive emission can be important in making a fine adjustment of experimental laser circuit parameters, in order to optimize laser pulse width to its minimum value.

5. ACKNOWLEDGMENTS

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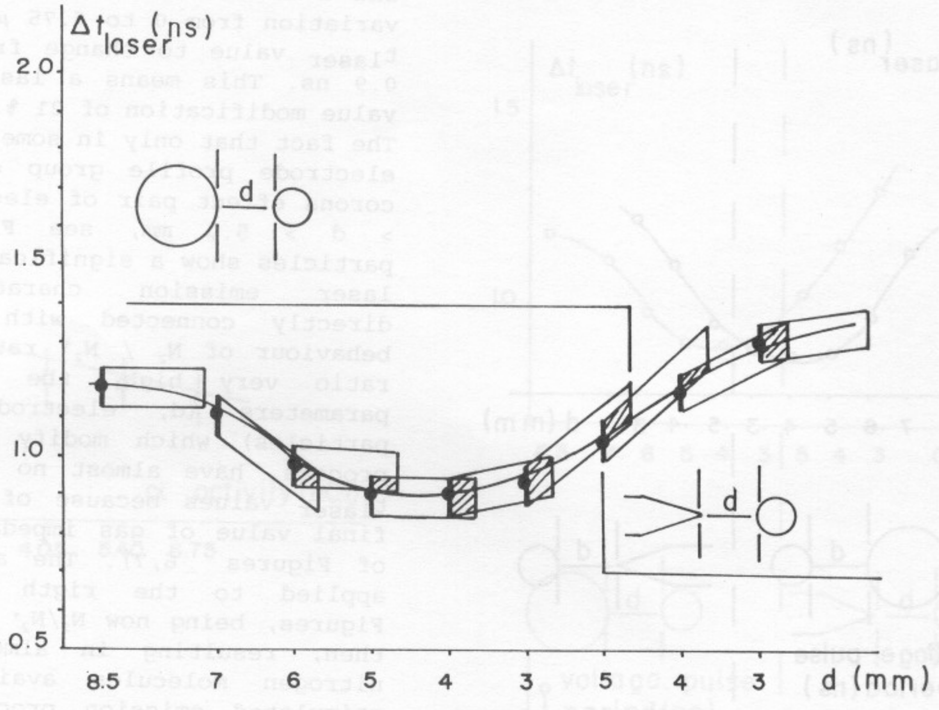

Figure 6. Similar to Figure 4, each area now corresponds to laser pulse width modifications detected when one to five ^{241}Am sources are introduced into the laser discharge tube, in the way specified in Figure 1-c. $p(N_2)$ = 37.5 torr.

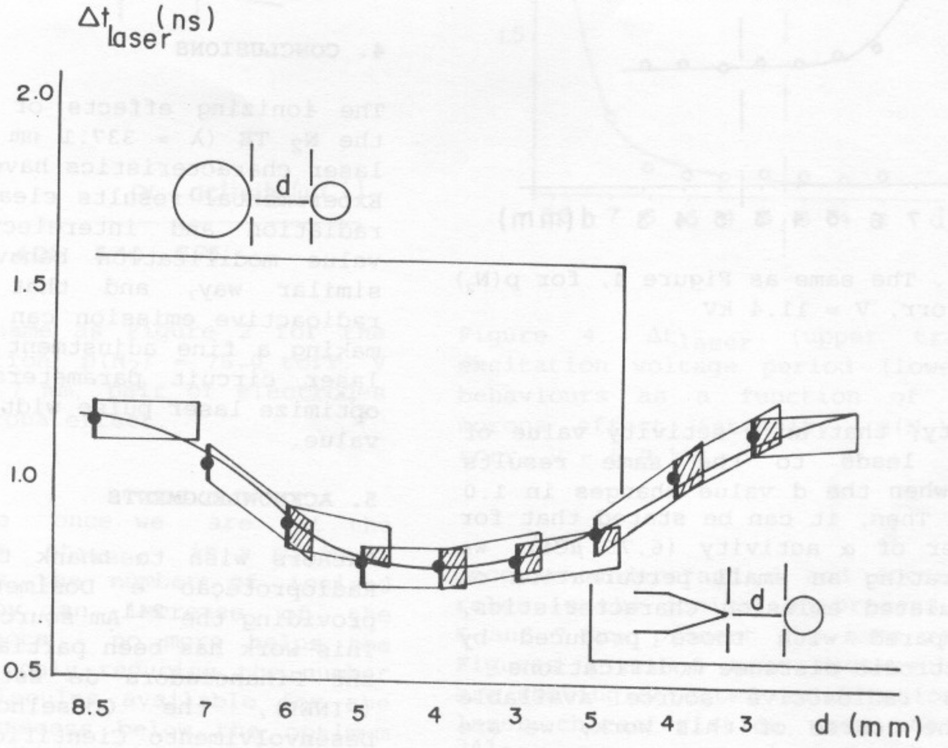

Figure 7. The same as Figure 6, for $p(N_2)$ = 75.0 torr

Pesquisa e Pós Graduação da Universidade Federal Fluminense (PROPP-UFF).

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