PARAMETRIC MEASUREMENTS ON A DOPED CO_2 TEA LASER

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Parametric measurements have been performed on a CO_2 TEA laser with a discharge volume of $6.5 \times 6.5 \times 45$ cm^3. The effect of a low ionization seed gas, tri-n-propylamine, upon amplification, power output and voltage-current characteristics has been measured. A small-signal gain of 4.8%/cm has been measured in a 1:1:3 mixture and a power output of 60 J/ℓ in a 3:11:21 mixture.

1. Introduction

It is well known that the performance of a simple wire triggered TEA laser improves drastically when a low ionization seed gas is added to the laser gas mixture [1−3]. Some explanations that have been given to this phenomenon are improved photo-ionization [1,2], and a modified electron energy distribution function [3−5] causing more optimal pumping and a shift of an attachment dominated discharge towards a more stable recombination dominated discharge. Negative effects have been reported in [3], where a depopulation of the upper laser level by TPA was measured. This letter describes parametric measurements on a $6.5 \times 6.5 \times 45$ cm^3 doped TEA laser module with a somewhat improved U.V. preionization system. The laser has a simple, robust, non critical construction and optical outputs in excess of 60 J/ℓ. In addition to all the effects mentioned, our measurements show that TPA also influences the discharge volume.

2. Experimental set up

The laser module is shown in fig. 1 and consists of two uniform field electrodes, a three stage marx generator and a U.V. preionization source. The electrodes have been cast from a brass that exhibits little internal tension after casting. These raw electrodes were milled then, until they had a Chang profile [6], with $k = 0.04$.
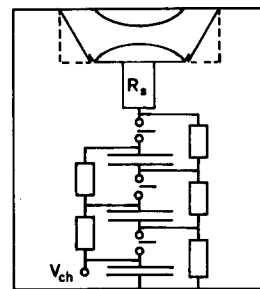

Fig. 1. Scheme of the excitation circuit and the laser head. R_s: series resistor 1.3 Ω, capacitors 0.3 μF, charge resistors 50 kΩ.

The air insulated marx generator consists of 3 air-pressurized spark gaps with mid-plane triggering, 3 capacitors of 0.3 μF and is connected with 12 cm wide stripline. It has a measured risetime of 20 ns and the circuit inductance is 250 nH. As a U.V. source we first used trigger wires [1,2], then knive edges [4], but finally a structure was developed that combines the simplicity of knive edges with the high U.V. production of sliding sparks. A cross section is shown in fig. 2. It is thought that with this construction the corona discharges from the knive edges are pulled towards the glass surface. When pulsed, it can be seen that the entire glass surface over the metal strip is covered with corona-like discharges. The construction is somewhat similar to the construction used by Ernst and Boer [7] Evidence for an improved U.V. production is found in the fact that with this construction the laser gas mix-
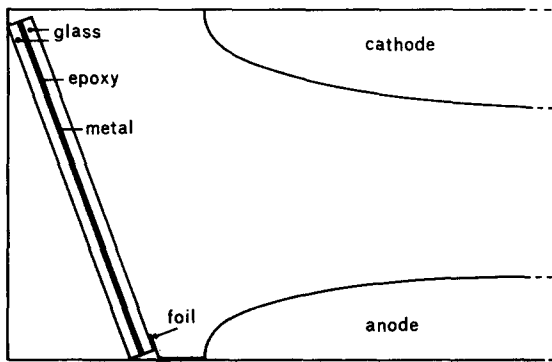
Fig. 2. U.V. photo-ionization source, consisting of a knive edge (stainless steel 0.1 mm foil strip) and a metal strip embedded in glass and epoxy.

Fig. 4. Calibration curve of the absorption cell. Vertical scale shows the transmission of the cell.

ture may contain 20% CO_2, while with the earlier U.V. sources glow discharges were obtained for mixtures that contained less then 8% CO_2.

3. The T.P.A. measurement

As the concentration of tri-n-propylamine is an essential parameter in our laser system, it has to be measured on line in a flowing gas system. It turns out that this is easily done with a U.V. absorption cell. The set up is shown in fig. 3, and consists of a high pressure mercury lamp with a quartz envelope, a 560 mm long absorption cell with quartz windows, a narrow band pass filter ($\lambda = 2555$ Å, $\Delta\lambda = 215$ Å) and a U.V. sensitive detector (I.T.T. F4115). The band pass filter was chosen because of its availability; a better choise seems possible as the Hg spectrum dips around this wavelength. The set up is calibrated by the injection of known amounts of T.P.A. in the closed cell. While calibrating, the cell is heated to $50°C$ to obtain a fast response. Measured absorption is shown in fig. 4. As can be seen the absorption does not follow Beer's law. Nevertheless the measured curve allows us to monitor

Fig. 3. Absorption cell to measure the TPA concentration in the laser gas mix. Hg: high pressure mercury lamp, W: quartz window, F: filter ($\lambda = 2555$ A, $\Delta\lambda = 215$ A), D: detector.

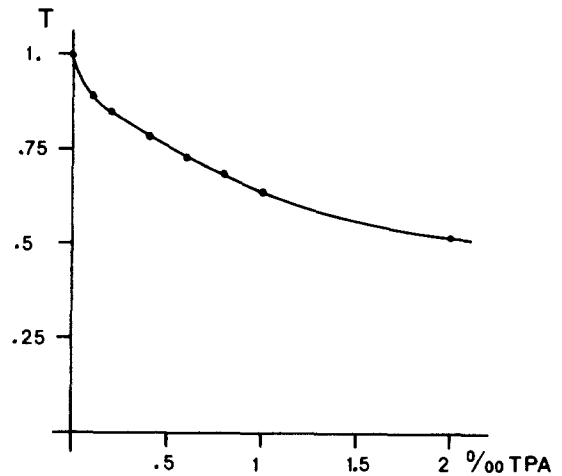the T.P.A. concentration of the mixture in the flowing gas system. A dependence of the absorption measurement upon the concentration of CO_2, N_2 and He was not found.

4. The module as an amplifier

The module is in fact a part of an amplifier chain. For that reason the small signal amplification has been measured in detail as a function of gas composition, TPA concentration, charge voltage and location in the discharge gap. The actual measurements are done with a 1W probe laser, stabilized at the P20 rotational transition in the 10.4μm branch, a LN_2 cooled HgCdTe detector and a Tektronix R7912 transient digitizer. When the module is fired, the peak small signal gain and the fwhm duration of the small signal gain pulse is measured.

The first measurement is shown in fig. 5. It gives amplification and gain pulse duration at the axis of the module for different gas mixtures with a fixed charge voltage and a fixed TPA concentration. It was established first that the best performance was obtained when the gas mix contained 40% molecular gases. Then the CO_2 concentration was varied within this 40%. As expected the small signal gain raises and the pulse duration shortens for increasing CO_2 concentrations.

Then the effect of the TPA concentration was measured. We found that unlike the results obtained in [3],
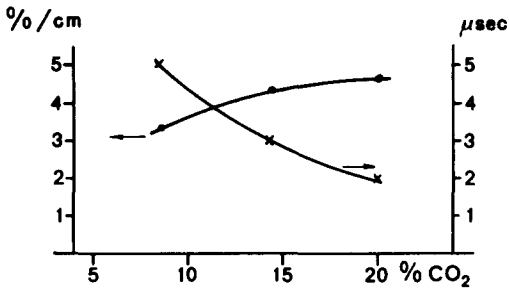
Fig. 5. Amplification and fwhm gain pulse duration of the module for gas mixtures containing 40% molecular gases and 100 ppm TPA. The charge voltage was 40 kV.

the TPA concentration did not affect the gain significantly for concentrations of 50–1000 ppm. In fact a spread in peak gain and gain pulse duration of less then 5% was found.

Next the spatial distribution of the gain between the electrodes was measured tangential and parallel to the electrodes. Parallel to the electrodes the measured gain is shown in fig. 6 for a 1:1:3 mixture doped with 200 ppm TPA. We see that for increasing charge voltages the gain region becomes wider, and that for a charge voltage of 40 kV the gain decreases at the center of the module. At higher charge voltages repeated arcing occurred for this gas mixture.

Tangential to the electrodes it was found that the gain is uniform.

5. The module as an oscillator

In this series of measurements the module is equipped with a copper mirror with a radius of curvature of 5 m and a plan parallel germanium window, both with an aperture of 9 cm. Again it was first established that the best results were obtained when the laser gas mixture contained 40% molecular gases. Fig. 7 gives the power output as a function of the charge voltage for some of these mixtures. The TPA concentration was held constant to 100 ppm. We see that the highest outputs are obtained for a 3:11:21 mixture of $CO_2:N_2:He$. For this gas mixture the TPA concentration was varied, which is shown in fig. 8. It was found that for this mixture the maximum output corresponded with the minimum TPA concentration. For a TPA concentration of 10 ppm and a charge voltage of 44 kV, the output obtained was 109 J. For this condition the active volume of the discharge was determined by scanning the output beam with a slit-shaped aperture. The scan is shown in fig. 9. This measurement gave an active volume of 1.78 ℓ, which means that the maximum obtainable optical output of the module is 61 J/ℓ.

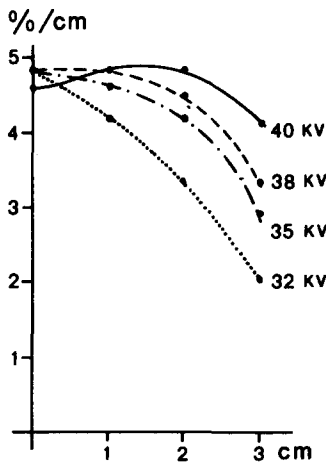The time dependent output intensity is also a func-

Fig. 6. Spatial gain distribution in the module, measured parallel to the electrodes. The horizontal scale gives the distance to the axis of the module. The laser gas is a 1:1:3 mixture, doped with 100 ppm TAP.
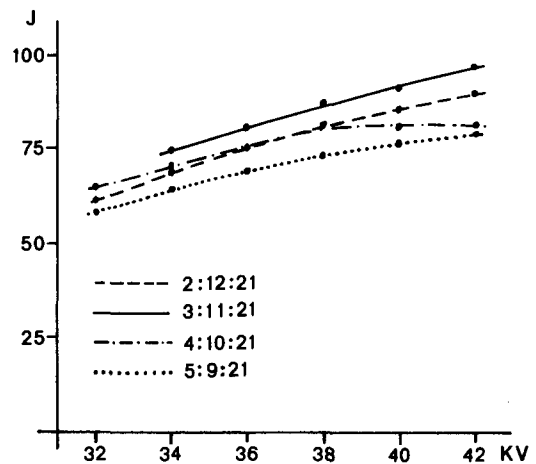

Fig. 7. Power output of the module as a function of the charge voltage. All mixtures contain 40% molecular gases, the TPA concentration is 100 ppm.
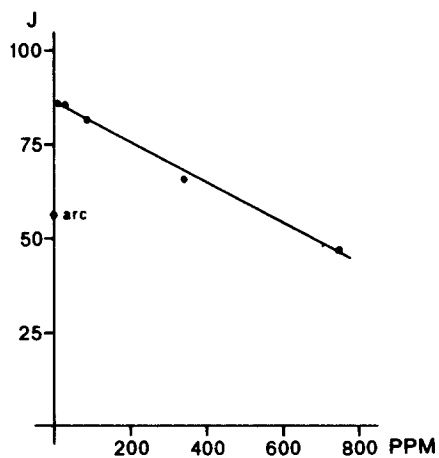
Fig. 8. Power output of the module as a function of the TPA concentration. The charge voltage is 36 kV, the laser gas a 3:11:21 mixture.

Fig. 10. Time dependent output intensity of the laser module. Mode beating, visible at the oscillogram, is not shown. The charge voltage is 40 kV, the laser gas a 3:11:21 mixture.

tion of the TPA concentration. We measured it at the axis of the module with a photon-drag detector. The results are shown in fig. 10. We see that the output intensity drops even more drastically then the total emitted power. To understand this, an other effect of TPA has to be introduced. This effect is shown in fig. 11. We scan the output beam for two different TPA concentrations and see that for an increasing
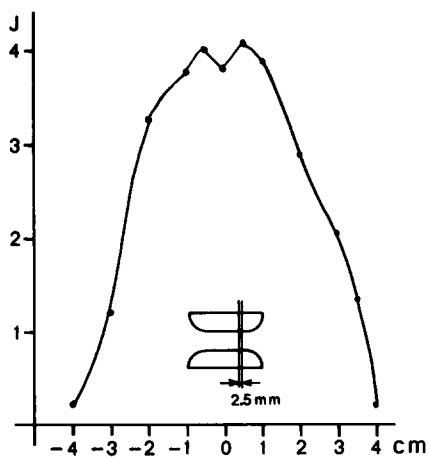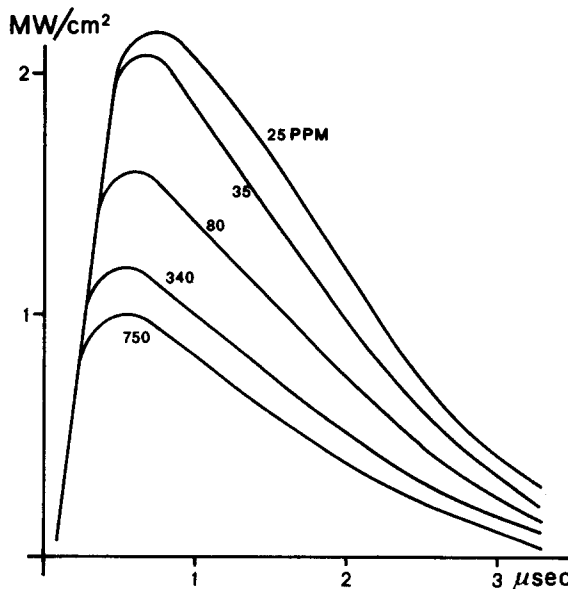
TPA concentration the beam, and thus the discharge, becomes wider. The laser gas is a 3:11:21 mix; for higher CO_2 partial pressures the effect becomes less pronounced.

Fig. 9. Scan parallel to the electrodes of the power output. The charge voltage is 44 kV, the laser gas a 3:11:21 mixture.
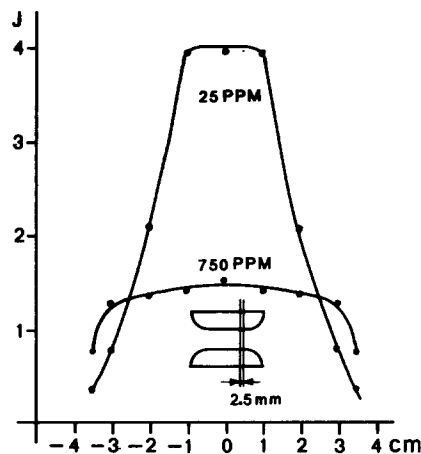

Fig. 11. Scan parallel to the electrodes of the power output for a heavy and a light doping in a 3:11:21 mixture. The charge voltage is 36 kV. Note that when the distance to the axis $d > 3$ cm, the limited aperture of the output mirror becomes important.

6. Voltage-current measurements

Finally the effect of TPA upon the discharge parameters was investigated for a 3:11:21 mixture. The results of this measurements are shown in fig. 12 and confirm the well established behaviour of a doped laser [3—5]. For high TPA concentrations (solid line) the peak current increases, while the laser voltage at which the discharge takes place decreases. From this measurement and the result shown in fig. 8 it must be concluded that a decrease in the plasma impedance does not necessarily give an increased power output of the laser. This should be expected when only the optimum E/n value of the plasma is taken into account [8]. Besides the widening of the discharge region a depopulation of the upper laser level [3] by TPA may account for this phenomenon.

7. Conclusion

Parametric measurements have been performed on a laser module in which TPA is an essential component of the gas mixture. The effect of the TPA concentration upon amplification, output power and voltage-current characteristics have been measured. Improved performance has been obtained by the use of a more powerfull U.V. source, which indicates that the effect of TPA upon photo-preionization must not be overestimated. A new effect of TPA, the increase of the discharge volume, has been shown. A new method to measure the TPA concentration in the laser gas mixture has been introduced. The module in its present form is simple, robust, reliable and well suited for every application in which high power pulsed 10 μm energy is needed.
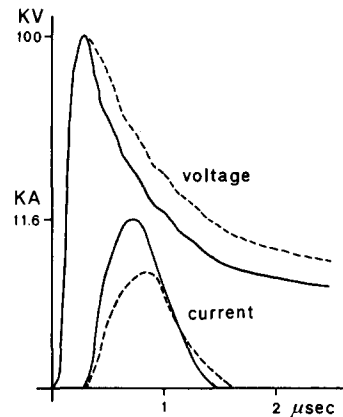

Fig. 12. Voltage- and current pulse of the module for a 3:11:21 mixture and a charge voltage of 35 kV. Dotted curve: TPA concentration of 10 ppm, solid curve: TPA concentration of 1000 ppm.

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