INVESTIGATIONS OF uv TEA N_2 LASERS, BASED ON CERAMIC CAPACITORS

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Transversely excited atmospheric nitrogen (TEA N_2) lasers with different length utilizing a "double" Blumlein-circuit, based on ceramic capacitors, and switched by spark gap were investigated. It has been shown that for optimum laser output not only the charging voltage, the repetition and the gas flow rate, but the separation and the angle of the laser electrodes has to be also taken into account. An attempt was made to determine the optimal conditions and the limit of the miniaturization with a given geometrical set up and electrical excitation.

Introduction

To make simple, miniaturized and compact pulse laser desings it has recently been practicable to utilize transversely excited atmospheric nitrogen (TEA N_2) lasers ($\lambda = 337$ nm) [1—3]. The pulse power of these lasers is several hundred kW and the half-width of the pulses are about nanosecond or subnanosecond [4—6]. Of the possible applications it is enough to mention the TEA N_2 laser pumped tunable dye lasers which have subnanosecond impulses without the mode-locking technique.

We reported in a previous paper [7] on our preliminary experiments concerning mainly the TEA N_2 laser with flat-plate Blumlein-circuit. These investigations revealed that finding the optimum working conditions for TEA N_2 lasers is a complex problem. The output pulse energy (E) and shape depend not only on the charging voltage (U) and the repetition rate (f), but also depend on the gas flow rate, the separation (d), and the angle (φ) of the laser electrodes [2—4], and the position of the spark gap, too. The first design with flat-plate transmission line was improved by applying discrete ceramic capacitors. In this paper we describe in details the results obtained with three different TEA N_2 lasers (varying the length) utilizing a "double" Blumlein-circuit, based on ceramic capacitors and switched by a triggered spark gap.

Experimental arrangements

The electric exciting transmission line was a "double" Blumein-type circuit (*i.e.* parallel connection of two Blumlein-circuit) based on barium titanate capacitors (KVI—12, 1 nF, 32 mm diam. × 12 mm).

In Fig. 1 the cross-section (a), the top view (b), and the circuit diagram (c) of our design built from 4×3 capacitors are shown, respectively. For longer desings 4×5 and 4×8 capacitors were applied. The length of the electrodes of the three lasers was 11.5, 19, and 30 cm, respectively with an effective length of the discharging spaces (l_{eff}) of 10, 17, and 28 cm. The laser electrodes (*1*) were made of 4 mm thick copper plates with circular profile (of 3 mm radius) and the remained edges were rounded off with 1 mm radius. The tips of the electrodes had a Rogowski-profile. The left electrode in Fig. 1 was fixed, while the right electrode was adjustable by two micrometers (*3*). The capacitors (*2*) were soldered on both sides of the electrodes and the outer terminals were connected with a flexible copper foil. The laser electrodes were closed between two fixed plexi glass plates (*4*). The nitrogen gas inlet (*6*) was either through the top plexi glass plate, or from side across the movable electrode (which was at ground potential), and so the gas flowed longitudinaly forward and backward between the electrodes.

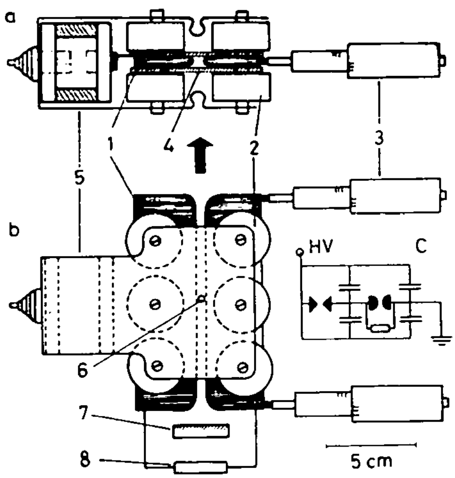

Fig. 1. Cross-section (a), top view (b), and circuit diagram (c) of TEA N_2 laser with 4×3 barium titanate capacitors in "double" Blumlein-circuit. 1 — pair of laser electrodes, 2 — capacitors, 3 — micrometers, 4 — plexi glass insulation, 5 — spark gap, 6 — gas inlet, 7 — flat mirror, 8 — resistor.

The Blumlein-circuit of our TEA N_2 lasers were switched by a triggered spark gap (*5*), in which the ignition electrode was in the middle of one of the main electrodes. The distance between the end of the discharging space and the 1st surface-aluminized flat mirror (*7*) was 3 cm. Our measuring set up was the same as published earlier [7].

Results and discussion

The importance of the setting of the laser electrodes to achieve optimum laser operation received little attention [3—6]. The present investigations were mainly focused onto the influence of spacing (we will use the following notations: d_f-rear, d_f-front electrode spacing) and angle of the laser electrodes on the laser pulse energy, the average power (P_a) and the pulse shape. We consider first those results which were obtained with a given angle between the electrode-pair ($d_f = d_r + 0.10$ mm) changing the total electrode separation (Fig. 2). (The flow rate of the nitrogen gas was at the minimum what was needed; the charging voltage was 14 kV with every experiments.)

As seen in Fig. 2 the optimum spacing of the electrodes with every laser is the same, 3.4—3.5 mm. If the difference from the optimum separation was ±0.4 mm (this corresponded to 10—15% of the absolute spacing) the pulse energy was only the half of the maximum value 0.03, 0.08, and 0.2 mJ, respectively.

In Fig. 3a the dependence of the energy/pulse and the average power on d_f, with d_r=3.40 mm, is shown. E and P_a exhibited maximum if the laser electrode spacing was sligthly larger at the front, than at the mirror (rear) end. If we plot the energy data (normalized to maximum values) versus φ (Fig. 3b), the half-width of $E(\varphi)$ became larger and larger by shortening the laser channel. The divergence of the output beam is determined by the geometry of the discharging space: if only a back-reflector was applied, the divergence of the radiation increased with decreasing l_{eff} ($\sim$6, $\sim$12, $\sim$20 mrad).

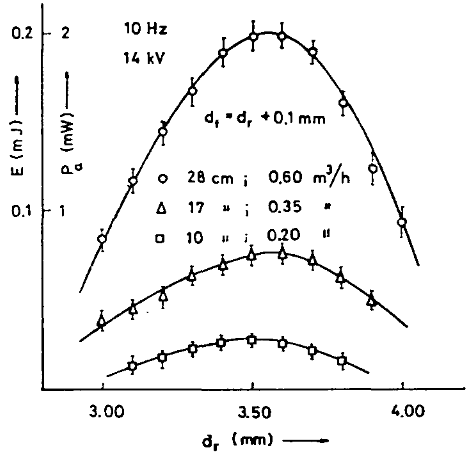

Fig. 2. Output energy/pulse (E) and average power (P_a) versus rear (d_z) electrode separation with different effective length (○ — 28, △ — 17, □ — 10 cm). $d_f = d_r + 0.10$ mm, f=10 Hz, U=14 kV and optimum gas flow.

We also investigated the influence of the charging voltage on E, with an electrode separation of d_r=3.40 mm and $d_f = d_r + 0.10$ mm, and with optimum gas flow rate in the case of each arrangement (Fig. 4a). In Fig. 4b the experimental data as a function of the effective length are shown. Fitting curves to the points of every voltage value and extrapolating to the l_{eff} axis, we can obtain the laser threshold from the point intersection and, thus, the limit of the size reduction in the case of every applied geometrical set up and electric exciting transmission line. According to Fig. 4b a TEA N_2 laser channel of 4—5 cm length could be built by applying higher charging voltages (14.5—15 kV). However, it may be a disadvan-

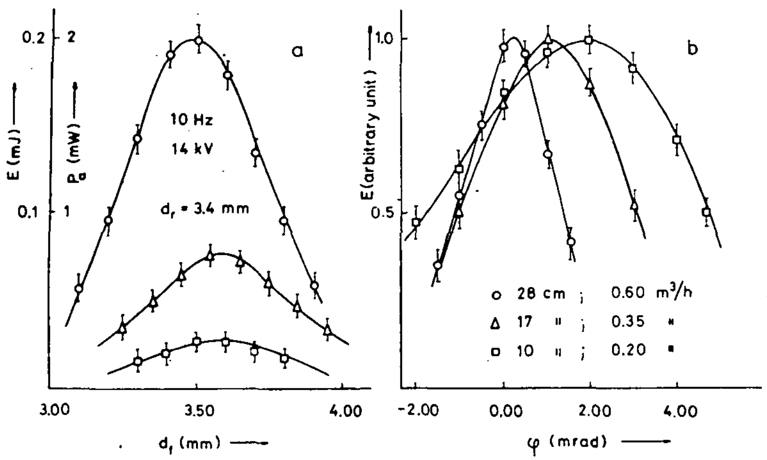

Fig. 3. Output energy/pulse (E) and average power (P_a) versus front (d_f) electrode separation (a and/or angle (φ) between the pair of electrodes (b), respectively with serveral effective length (○—28 □ — 17, △ — 10 cm). d_r=3. 4 mm, f=10 Hz, U=14 kV and optimum gas flow

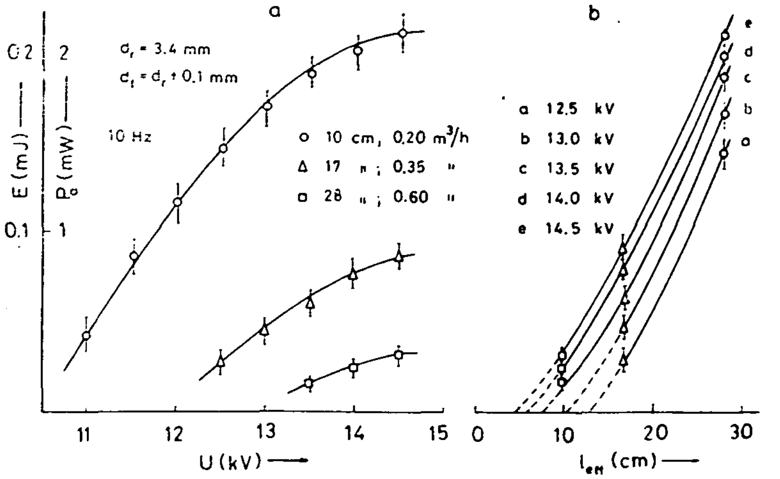

Fig. 4. Influence of charging voltage (U) (a), and the effective length (l_{eff}) (b), on the output energy (E) or average power (P_a). ○ — 28, △ — 17, □ — 10 cm; d_r = 3.4 mm, d_f = d_r + 0.10 mm, f = 10 Hz and optimum gas flow.

tage of this short laser channel that the optimum laser action can be obtained at relativly large electrode separation (3.4 mm), too, what means further increase of divergence.

The influence of the flow velocity (dV/dt) of the nitrogen gas stream (technical grade, purity 98%) on E or P_a is shown in Fig. 5. The output energy/pulse exhibited saturation with increasing flow rate in the case of every design. The needed quantity of nitrogen parallelly increased with the length of the laser channel. These values were ~0.2, ~0.4, and ~0.6 m³/h increasing the effective length.

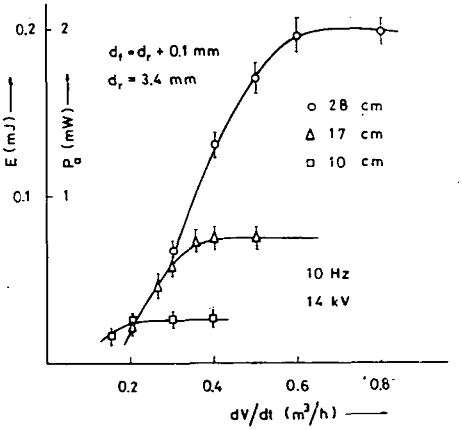

Fig. 5. Output energy/pulse (E) or average power (P_a) versus the flow rate (dV/dt) of nitrogen gas with several effective length (○ — 28, △ — 17, □ — 10 cm). d_r = 3.4 mm, d_f = d_r + 0.10 mm, f = 10 Hz, U = 14 kV.

The laser pulses were gaussian and their halfwidth were 0.7, 0.9, and 1.2 ns, respectively.

Further developments of TEA N_2 lasers with ceramic capacitors (and flat-plate also) transmission line can be achieved by considering the following new possibilities:

— Significant decrease of divergence and increase in output power may be realized applying an output coupler with short (5 cm) laser channel [3].

— [1] reported that with increasing discharge length the pulse energy does not increase linearly, but in fact, it becomes constant above 40 cm. Whereas [8] reported a linear increase in E with the discharge length, till 60 cm. According to our experience it is not worth building longer TEA N_2 laser channels than 30—35 cm. If higher output energy is necessary, the coupling and synchronization of two TEA N_2 lasers, as described in [9], may provide the solution.

In conclusion, this preliminary work on TEA N_2 lasers based on ceramic capacitors demonstrates that the energy/pulse of these designs is the same as it is at TEA N_2 lasers with flat-plate Blumlein-circuit, but the sizes of the former lasers are smaller. So it is possible to develope a simple, versatile and easily movable *uv* pulse laser which may be applied both in laboratory or in the common practice.

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ИССЛЕДОВАНИЯ «uv TEA N_2» ЛАЗЕРОВ ПОСТРОЕННЫХ ИЗ КЕРАМИЧЕСКИХ КОНДЕНСАТОРОВ

Б. Немет, И. Шанта., Л. Козма и Б. Рац

Исследовались несколько азотных лазеров различной длинны, возбуждённых поперечным разрядом в УФ области при давлении 760 торр (uv TEA N_2), работающих« двойным«, построенным из керамических конденсаторов, контуром Блумлеина, с управляемым разрядниковым включателем. Показано, что необходимо принимать во внимание не только напряжение, частоту повторения импульсов и количество азота для оптимальной интенсивности и стабилизации лазера, но растояние и угол между лазерными электродами тоже. Установлены оптимальные условия и предел уменьшения при данных геометрических параметрах установки и электрического возбуждения.