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Longitudinal N_2 laser driven by a Marx-bank generator

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N_2 longitudinal laser driven by Marx generator is reported. The energy generation and the shot to shot stability of the UV superradiant pulses at 337 nm were studied as functions of various parameters (the number of Marx generator stages, tube length, gas pressure, input voltage and capacity of dumping capacitors). The results show that the output energy and the laser efficiency increase with the number of stages in the Marx-bank driver for a sufficiently long tube. From the results it can be also seen that it is possible to decrease the instability of the laser by a careful adjustment of the gas pressure and input voltage, without decrease of the output energy. We have also studied the influence of dumping capacitors on the efficiency of laser. It has been found that there exists an optimum value of this capacity.

1. Introduction

The longitudinal-discharge pumped N_2 pulse laser when compared with the transversally pumped one is characterized by a simpler design and its beam quality is much higher. Recently, longitudinal-discharge pumped excimer lasers have also appeared [1], [2]. (Such lasers are much more effective UV radiation sources than N_2 lasers). Longitudinal-discharge pumped lasers can also work at high repetition rate on the order of 10^4 Hz without gas changing [3]. They would, therefore, be useful light sources for pumping dye lasers. It should be mentioned that a laser of very good stability is necessary to improve the averaging of experimental data. It seems therefore interesting to investigate the properties of the longitudinal laser system in more detail.

When high laser energy output is needed, high voltage pulses have to be used for the medium excitation. Continuous use of high voltage for excitation is, however, associated with frequent and dangerous electric breakdowns. In order to overcome the breakdown problem a high voltage system based on the Marx network was used. The low input voltage is a great advantage of this system.

2. Apparatus

Figure 1 shows a schematic diagram of the experimental set-up. The discharge tube was a piece of glass capillary of length $l = 26$ or 52 cm and 2 mm i.d. Two

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aluminium electrodes and one totally reflecting aluminium mirror were used. The high voltage could be varied up to 20 kV. After triggering the spark-gap in the Marx generator the energy from storage capacitors C_M (each of them of capacity

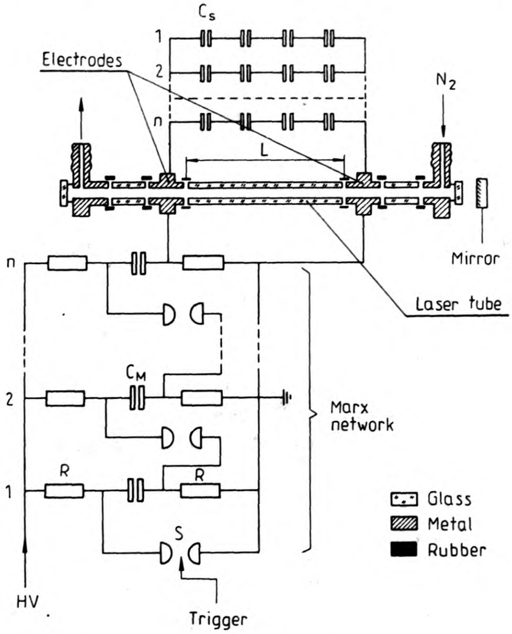

Fig. 1. Experimental set-up. L – glass capillary, C_M – storage capacitor (5 nF, 25 kV), C_S – dumping capacitor (500 pF, 30 kV), R – resistance (25 k, 25 W), S – spark-gap, n – number of steps

5.0 nF and rated for 25 kV) was transmitted to a line made of discrete components. The line was formed of a set of "doorknob" capacitors of 500 pF each. The dumping capacity C_S of this line could be changed from 125 to 750 pF.

Each spark gap in the Marx generator has a plexiglass case of cylindrical symmetry. The spark gap electrodes, made of aluminium, have the form of discs with rounded edges. The electrode distance can be adjusted continuously according to the laser operation voltage. The first spark gap is triggered via a trigger pin incorporated to ground electrode disc. In some of the generator spark gaps of such a system, continuous breakdowns do not occur. We used $R = 25$ kΩ, 24 W resistor in Marx generator. The repetition rate was 3 Hz. This value was limited in our experiment by resistor rating.

The essential property of the Marx-bank system is that the storage capacitors may be charged jointly and then discharged in a series connection. The output energy can be increased by increasing the number of stages. We tested an N_2 laser system driven by a Marx generator, with up to four stages.

3. Results

In order to test the usefulness of the Marx generator (MG) for longitudinal pumping of N_2 lasers the energy and reproducibility of the laser pulses were measured thoroughly with a Multichannel Pulse High Analyser (MCA). The spectrum of pulses of different amplitudes was taken by the MCA and plotted using an X–Y recorder or punched on a tape. The spectrum of pulses has a distribution similar to Lorentzian line shape. From this spectrum the number of channels ΔN at Full Width at Half Maximum (FWHM) was determined. The number of channels with the largest number of counts, which is proportional to the average laser energy (E_g), was denoted by N_{max}.

The average laser energy (E_g) and shot-to-shot amplitude stability ($\Delta N/N_{max}$) have been measured for different laser tube lengths, gas pressures and charging voltages per capacitor stage. Each value of E_g or $\Delta N/N_{max}$ was obtained as an average of about 1500 pulses accumulated in MCA.

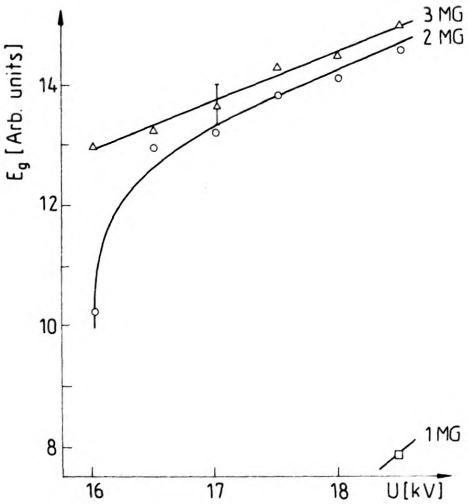

Fig. 2. Output energy for 1, 2 and 3 stage Marx-bank driver as a function of the charging voltage per capacitor stage (laser length 26 cm, pressure 20 hPa)

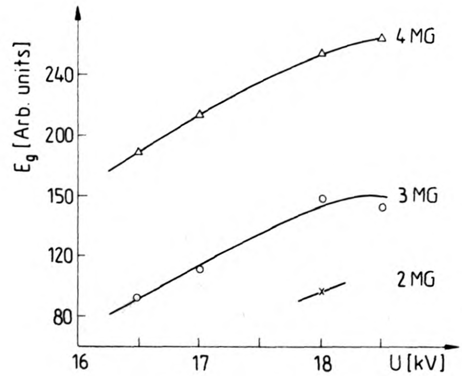

Fig. 3. Output energy for 2, 3 and 4 stage Marx-bank driver as a function of the charging voltage per capacitor stage (laser length 52 cm, pressure 20 hPa)

Figures 2 and 3 show the N_2 laser output energy as a function of the charging voltage. The *n*-MG symbols in figures indicate the numbers of stages used in the measurements. The data given in Figs. 2 and 3 were obtained with the 26 and 52 cm long discharge tubes, respectively. The pressure in both cases was 20 hPa. For the 2-stage MG, the energy of the laser with the 52 cm long tube is about 5 time higher than that of the laser with the 26 cm tube. For the 4-stage MG the output energy increased twenty times. Figure 4 shows the laser relative output energy (normalized to unity at the maximum) plotted against the N_2 pressure for the 3- and 4-stage MG. The charging voltages for the 4- and 3-stage MG were 18 kV and 17 kV, respectively. For all the measurements mentioned above the capacity of the dumping capacitors was 375 pF.

The relative output energy generation (normalized to unity) as a function of the capacity of the dumping capacitor is shown in Fig. 5. The measurements were made for 4- and 3-stage MG with the 26 cm long laser capillary and 17 kV charging voltage.

A laser which is to be used for spectroscopic investigations has to be pumped by a laser with good shot-to-shot stability. Therefore a detailed experimental analysis of the stability was carried out. The parameter $\Delta N/N_{max}$ was tested for

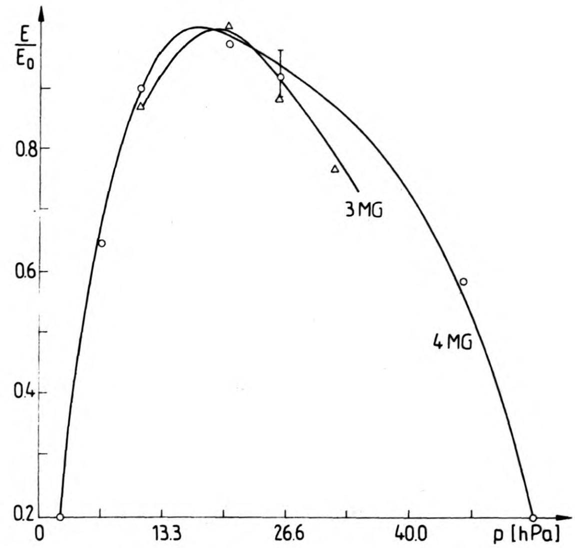

Fig. 4. N_2 laser output energy as a function of pressure (p) for different numbers of Marx generator stages (charge voltage 18 kV for 4 MG, 17 kV for 3 MG)

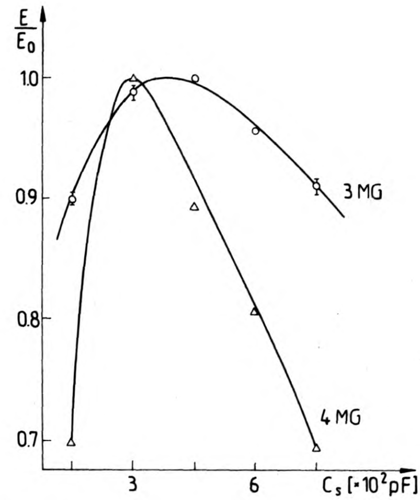

Fig. 5. Output energy as a function of the dumping capacitor value for different numbers of stages (laser length 26 cm, pressure 20 hPa, charging voltage 17 kV)

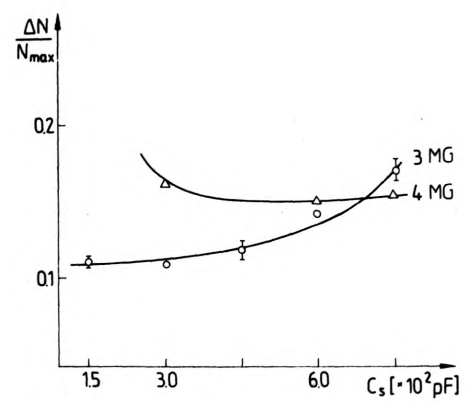

Fig. 6. Instability of laser pulses vs the dumping capacitors value for different number of stages (laser length 26 cm)

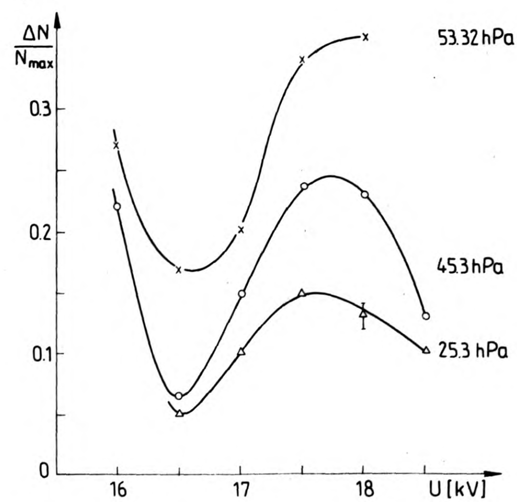

Fig. 7. Instability of laser pulses plotted against the charging voltage for different gas pressures (laser length 26 cm, 4 stage Marx-bank generator)

two different cases. The results are shown in Figs. 6 and 7. The instability of the laser pulses at different capacities of dumping capacitors in a 3- and 4-stage MG is presented in Fig. 6. Figure 7 shows the instability of the laser pulses as a function of the charging voltages for different N_2 gas pressures. The measurements were carried out for a 4-stage MG. In both the cases the capillary was 26 cm long. Figure 8 shows the relative output energy of the N_2 laser tube as a function of the

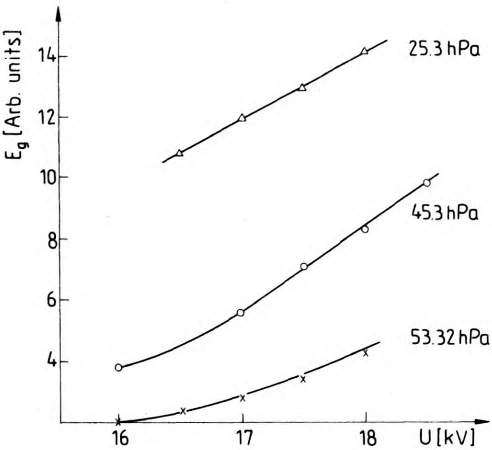

Fig. 8. Output energy of the N_2 laser tube as a function of the charging voltage for different N_2 pressures (laser tube length 26 cm)

charging voltage for different N_2 pressures. The measurements were made with the laser tube 26 cm long. As can be seen from Fig. 8, for the optimum pressure, the output energy increased approximately linearly with the charging voltage. For other pressures this dependence was not linear.

4. Discussion

It may be concluded from Figs. 2 and 3 that the laser output energy is not only a function of the input discharge energy, but that it also depends strongly on the capillary length. When the capillary is too short the output laser energy increases slowly with the laser input energy and is almost independent of the number of stages in MG. The above conclusion may be drawn from Fig. 2. When the laser tube is long enough the output energy increases with the increasing number of stages in the Marx-bank generator (Fig. 3). This is probably connected with the fact that for a long capillary the mean energy of electrons in the discharge is lower than the optimum for the excited $C^3\pi^+ uN_2$ state [4]. When the pressure and capillary length are constant, the mean energy of electrons can be increased by increasing the charging voltage or, much more effectively, by increasing the number of stages in the Marx generator. It should be taken into consideration that the voltage does not increase proportionally to the number of stages. The efficiency of the Marx-bank generator depends on such parameters as the value of the resistor R or that of the stray capacitance between C_m capacitors [5].

The output laser energy depends also strongly on the capacity of dumping capacitors (see Fig. 5). Similar dependence for the output laser energy, observed by RUHL et al. [6], is stronger for large number of stages. Generally, the instability of the laser increases with the number of MG stages, but is depends also (see Figs. 6 and 7) on the gas pressure and the charging voltage. This instability may be reduced by a careful adjustment of the gas pressure and input voltage without a significant decrease of the output energy. Since the instability depends also strongly on the precise adjustment of all the spark-gaps in the Marx-bank generator, it can be reduced by using an active spark-gap drive [7].

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Лазер с продольным разрядом управляемым генератором Маркса

В работе описан лазер на азоте с продольным разрядом, управляемый генератором Маркса. Выходная энергия и временная стабильность энергии импульсов для $\lambda = 337.1$ nm исследовались в зависимости от разных параметров (числа каскадов Маркса, длины разрядной трубки, давления газа, входного напряжения и паразитной ёмкости). Полученные результаты показывают, что для достаточно длинной разрядной трубки выходная энергия и отдача лазера возрастают с ростом числа каскадов генератора Маркса. Показано, что является возможным увеличение стабильности работы лазера (при его неизменной выходной энергии) путем старательного подбора давления газа и входного напряжения. Исследовалось тоже влияние паразитной ёмкости на производительность лазера. Было найдено, что существует оптимальная величина паразитной ёмкости.