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Longitudinal discharge travelling wave pulse laser device

The pulse laser device with a segmented discharge tube and a travelling wave in axial field is described. The typical characteristics of the N_2 laser working on the base of this system are presented. This system is also useful as a laser device producing shorter radiation in UV and VUV.

1. Introduction

The pulse lasers in the ultra-violet, especially the N_2 laser, have a high peak power and short risetime. For this reason they are used as a pump light source for dye lasers. Some of the N_2 laser constructions can be used to produce shorter laser radiation, for instance for the H_2 laser working in the vacuum ultra-violet in the Lyman band at $\lambda \simeq 160$ nm. In such a pulse laser the inversion between the laser levels depends on the magnitude of the discharge current and its risetime which must be of the order of 1–10 ns. In these devices it is very important to use for excitation a travelling wave which decreases the width of the laser pulse and increases its peak power.

At present there are many constructions of a simple, high power and low cost pulsed lasers. Generally, there exist two types of the pulsed lasers devices. These two types differ mainly in the kind of discharge, which may be either longitudinal or transverse. The first type does not allow to obtain high power (with the exception of the pulsed electron beam excitation). In axial field devices, the electron breakdown time depends on the distance between the electrodes [4,6]. In some cases the time of breakdown is of the same order as the life time of the upper laser level of the lasing molecules. In practice the optimal distances between the discharge electrodes are about 30 cm [2]. By increasing the length of the laser tube no higher peak power of the laser pulse can be obtained. This problem can be solved using the segmented laser tube, as it was shown by Borgström [5] and Ross [8].

In this paper we present a simple laser device with a segmented discharge tube supplied by a Blumlein pulse generator. For this laser some typical characteristics are also given.

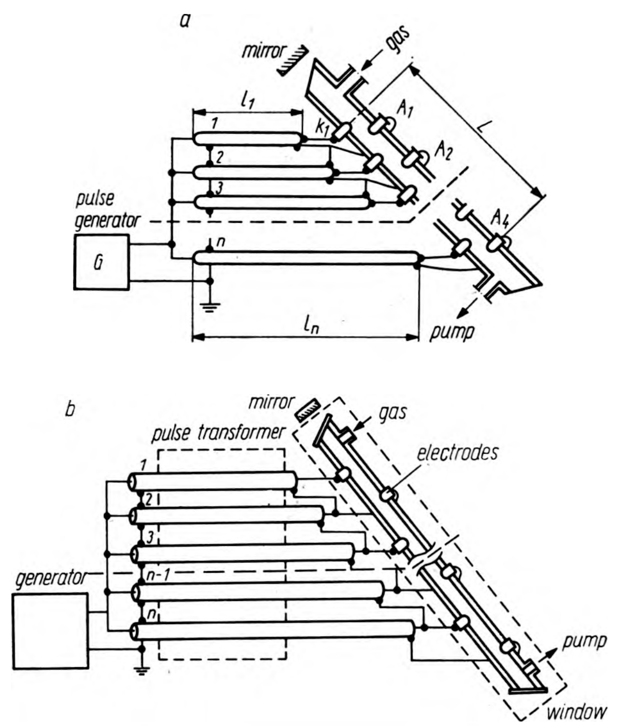

Fig. 1. Schematic diagram of the laser device with coaxial cables

a) connected in parallel at the input and output, b) connected in parallel at the input and in series at the output

2. Experimental set-up

The segmented longitudinal discharge tube of the laser device is connected to the pulse generator. The pulse generator consists of a storage capacitor, spark gap, and a system of coaxial low impedance delay lines carrying energy to the laser tube. Fig. 1a shows the experimental set-up. The lengths of the two neighbour coaxial cables carrying energy to the n-th and $(n-1)$-the segment of the laser tube differ from each other by

$$\Delta l = l_n - l_{n-1} = \frac{\Delta L}{\sqrt{\varepsilon_r}}, \tag{1}$$

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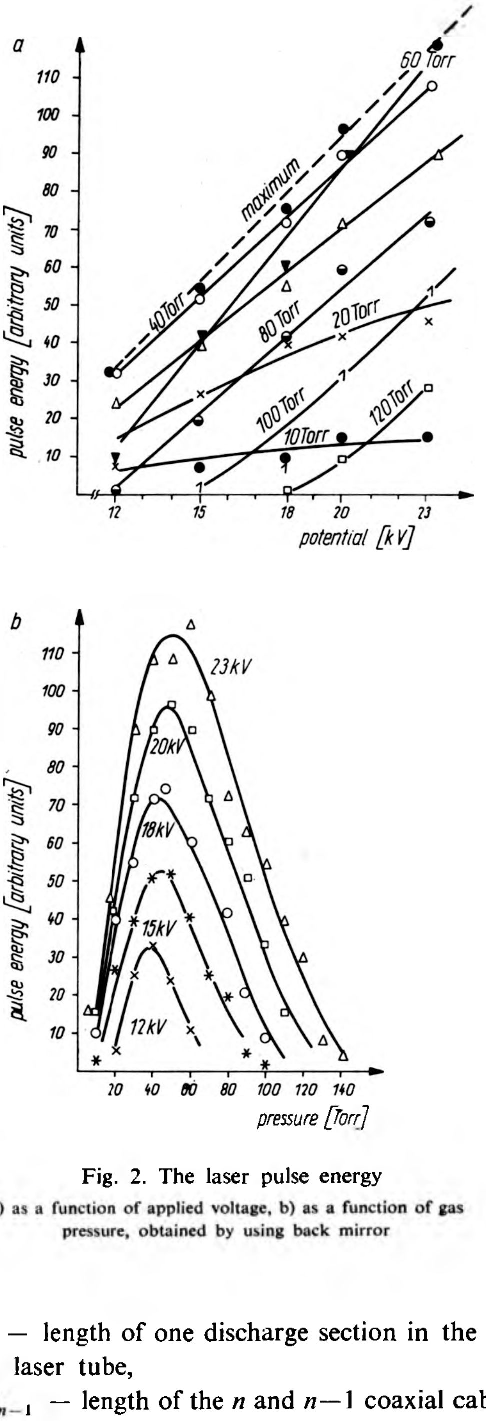

Fig. 2. The laser pulse energy
a) as a function of applied voltage, b) as a function of gas pressure, obtained by using back mirror

where:

ΔL — length of one discharge section in the segmented laser tube,

l_n, l_{n-1} — length of the n and $n-1$ coaxial cables, respectively,

ε_r — relative dielectric constant $\varepsilon_r = \dfrac{\varepsilon}{\varepsilon_0}$

In our arrangement the cables are connected in parallel at the input and in parallel at the output. The outputs of the delay lines are connected to the discharge electrodes as shown in fig. 1a. This system was practically tested as a source of laser pulse in following nitrogen on the transition

$$C^3\pi_u(v'' = 0) \to B^3\pi_g(v' = 0)$$

at $\lambda = 337.1$ nm. In our experimental set-up the lengths of the discharge section and coaxial cables are 3 cm and 75–110, respectively. The active length ot the laser tube was 57 cm. We used 120 coaxial cables, 50 Ω each. These cables were connected by six to each discharge section. A storage capacitor (of about 18 nF) and a spark gap system were specially constructed in order to minimize the inductances of connectors. The laser tube and the discharge electrodes were made of plexiglass and iron, respectively. Spark gap system consists of brass electrodes mounted in teflon.

The energy and the spectrum of the laser pulses were measured using thin film Al-Bi-Al thermocouple and greating spectrograph PGS-2, respectively. The pulse shape was measured with a fast photodiode using sampling method. The line structure of laser pulses was similar to that obtained by Tocho et al. [7]. Some variations observed in the light beam structure were due to differences in tube construction, gas pressure, and appiled voltage.

Fig. 2 shows the laser pulse energy as a function of applied voltage for different N_2 pressures, and as a function of gas pressure for different voltages, obtained by using back mirror. The same relation obtained without back mirror is presented in fig. 3.

The gain down the laser tube calculated from fig. 4 is about 30 dB/m. The ratio of forward to

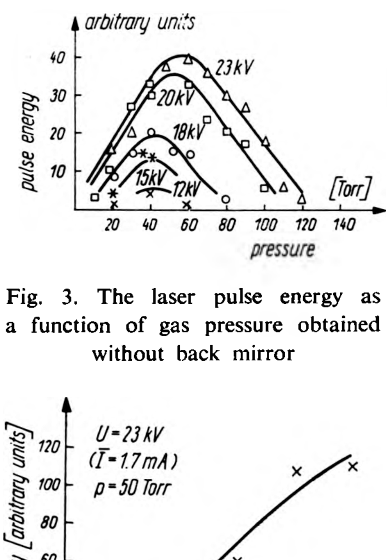

Fig. 3. The laser pulse energy as a function of gas pressure obtained without back mirror

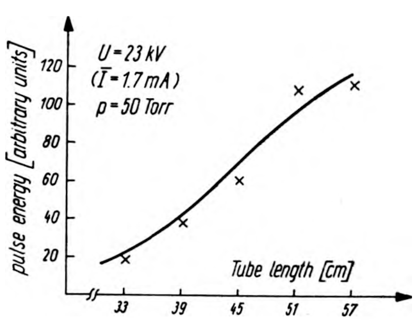

Fig. 4. The laser pulse energy as a function of tube length obtained for $U = 23$ kV and $p = 50$ Torr of nitrogen

backward emission from the two ends of the tube is equal to 10:1, for the gas pressure 50 Torr and applied voltage 23 kV. The beam divergence was about 10 mrad. The determined half-width of the laser pulse was 5.5 ns, and its shape is given in fig. 5. It may be expected that an improved construction of the

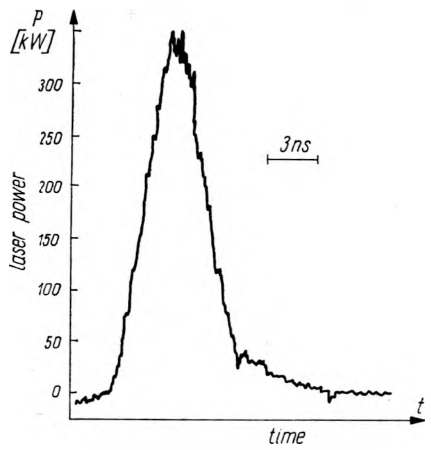

Fig. 5. Typical shape of the laser pulse obtained by using sampling method

pulse generator will allow to reach the half-width of the order of 1 ns. The pulse energy being about 2 mJ gives the pulse peak power of 350 kW, and total efficiency of about 0.5%.

It must be mentioned that it is possible to build the segmented pulse laser device where the coaxial cables are connected in parallel at the input and in series at the output, according to scheme shown in fig. 1b. In this system the cables must be mounted on the ferromagnetic cores. Like in the laser of the first type, the cables have different langths which for the individual section are given by equation (1). In this way a special arrangement of a travelling wave pulse transformer can be obtained. In our case this arrangement worked without core (with air core) giving discharge in N_2 but without stimulated emission. New different versions of this laser device using ferromagnetic cores being presently constructed.

3. Final remarks

In the presented laser device a travelling wave excitation in axial electric discharge was obtained. The pulsed lasers of the construction shown in fig. 1a can work at very low voltage (one of our N_2 laser worked at the applied voltage about 3 kV). In this lasers the light pulse duration can be changed by assuring suitable differences between lengths of the coaxial delay lines. The cross-section of the laser light beam is round. The typical characteristics of such a laser device are similar to those of the transverse ones.

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Лазер возбуждаемый вдоль оси с бегущей волной

В работе представлена импульсная система лазера с сегментной разрядной трубой, возбуждаемого вдоль оси, с бегущей волной. Представлены также типичные характеристики лазера, работающего на основе этой системы. Такую систему можно применять для конструкции импульсных лазеров в пределе UV и VUV.

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