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Construction and parameter description of a nitrogen laser

A simple N_2 laser has been constructed. Output power of 0.5 MW and about 5 ns FWHM pulse duration has been obtained. The dependences of the peak power energy and duration of the laser pulse on the tension of the power supply nitrogen pressure, and repetition rate were measured. The distribution of radiation intensity in a cross-section of the laser beam was also studied in relation to the repetition frequency of the laser.

In 1963 HEARD [1] obtained a laser action by means of fast electrical discharge in nitrogen. The radiation spectrum of this type laser is complicated; it consists of approximately 30 lines in the ultraviolet region. Over 99% of the energy is emitted in the form of radiation of the wavelength 3371 Å, corresponding to the transition from the $C^3\pi_u$ to $B^3\pi_g$ states in the nitrogen molecule [2].

A necessary condition for obtaining population inversion of the N_2 molecule is a short risetime of electrical discharge in the gas, because the lifetime of the $C^3\pi_g$ state is about 40 ns [3].

We feel that of many possible variants of a medium power nitrogen laser that, described in the present paper, can be most easily constructed under laboratory conditions. It consists of a circuit in which energy is transmitted indirectly by means of an artificial delay line as proposed by SCHENK and METCALF [4]. Electrical circuit of this laser is shown in fig. 1.

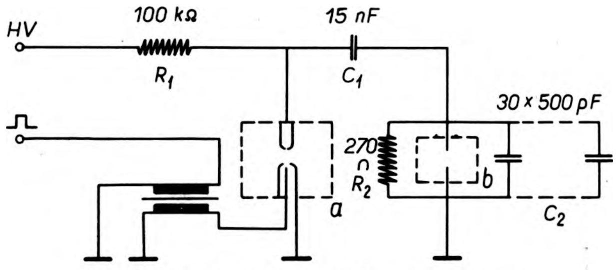

Fig. 1. Electrical circuit of the nitrogen laser

After high voltage is switched on capacitor C_1 is charged trough the resistances R_1 and R_2 to the power supply voltage. The resistance R_2, being low, the voltage in capacitor C_2 and in discharge channel during charging process is low and not sufficient for breakdown. When the spark gap is switched on, the positive electrode of capacitor C_1 becomes earthed, and the capacitor C_2 is charged with the negative tension pulse which appears on the second electrode of capacitor C_1 (the spark gap switch time is much shorter than the discharge time of capacitor C_1).

The charging of capacitor C_2 ends with the breakdown in the discharge channel. After breakdown the battery of capacitors C_2 discharges rapidly in a circuit consisting of capacitors C_2 and the discharge channel. (The influence of resistance R_2 may be omitted because of the negligible resistance of the ionized discharge channel.)

Since the dispersed inductivities of this circuit are low, the switch time of the spark gap (or thyratron) need not be so short as in other types of lasers [5, 6].

The current risetime in the channel and its peak intensity — and thereby the power of the laser — is a complicated function of channel pressure, power supply tension and spark gap switch time, because of the nonlinear resistance of the channel and gap.

Fig. 2 presents a cross-section of the laser discharge channel. Nitrogen is supplied in the region of the windows of the laser and evacuated in the middle part of the channel. Such an arrangement prevents contamination of the laser windows. The glass plates forming the discharge channel were mechanically reinforced by a polyester laminate. The distance between the channel electrodes is 2.1 cm. Because of radio noise arising during laser action an additional internal screen has been installed.

Chemical actionmetric methods were used to measure the energy of the laser pulse [7, 8].

A 25 ml flask containing a 0.0006 M solution of $K_3Fe(C_2O_4)_3$ was exposed to laser pulses. After addition of complexing agents, absorption of the irradiated solution was examined spectrophotometrically at $\lambda = 5100$ Å. This allowed to determine in actionometric solution the concentration of Fe^{++} ions resulting from the irradiation, and the absolute number of photons absorbed by the solution.

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Actionmetric measurements of the laser pulse energy were carried out at a tension of 20 kV, pressure 40 Tr, and frequency 33 Hz. The measured energy

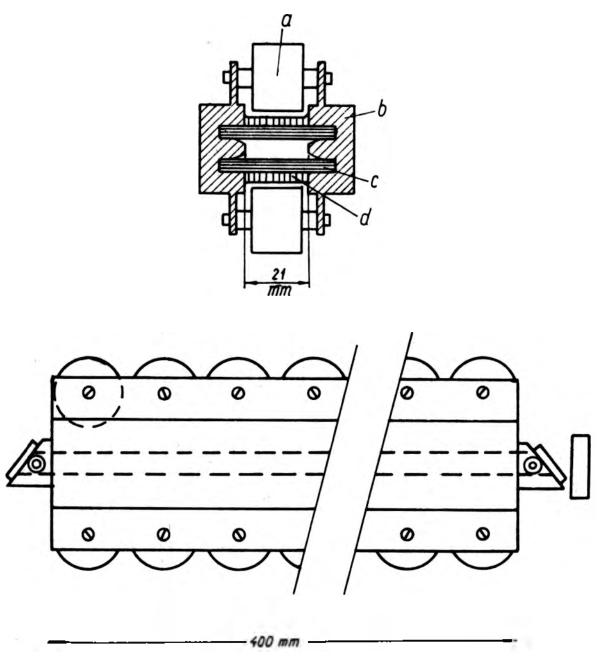

Fig. 2. Cross-section of the laser discharge channel: *a* — capacitor 500 pF/25 kV, *b* — aluminium electrode, *c* — glass plate, *d* — polyester laminate

of the pulse amounting to 0.75 mJ, corresponds to a peak power of the pulse, equal to 125 kW.

To determine the optimal constant value *E/p* of the laser the relations between the peak power, pulse duration (FWHM) and working parametres of the laser were determined by means of a sampling oscilloscope (type OS 150), and a fast silicone photodiode. The repetition rate of the laser was measured with a digital frequency meter (type PFL 16).

Similar relations for another arrangement of the laser (with strip line and travelling wave) were studied in paper [9].

Our measurements were conducted for a laser without mirrors, or with one mirror, and for a laser with a resonator. A quartz plate inserted in front of the laser window served as a second mirror in the resonator.

Constant peak power lines of the pulse, as a function of the power supply tension and nitrogen pressure, are presented in fig. 3a, b, c: (a) laser without mirrors, (b) laser with one mirror, and (c) laser with a resonator. In case (b), the laser works within a much broader range of pressures and at lower tensions than in case (a). In case (c) the power is much higher, the optimum occurring at lower tensions; in this case the range of pressures within which the laser functions efficiently is the broadest one.

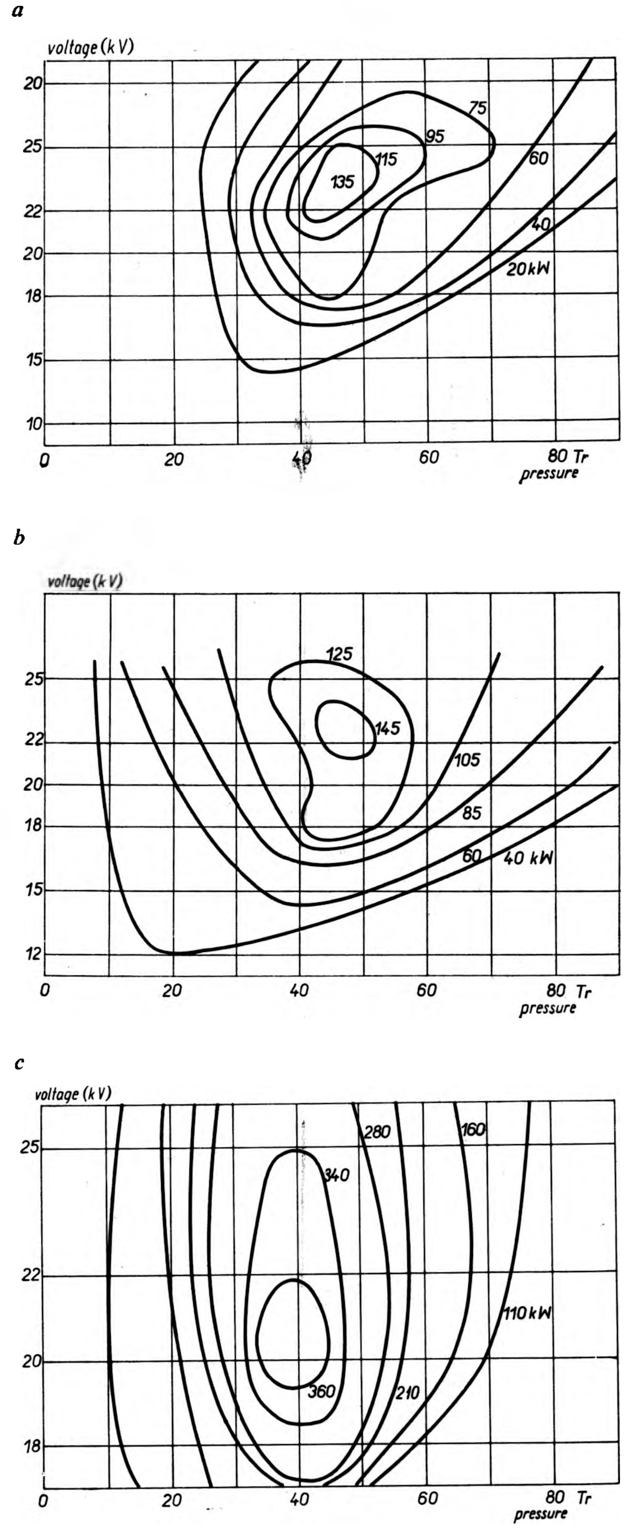

Fig. 3. Laser peak power vs. the power supply tension nitrogen pressure: a — laser without mirrors, b — laser with one full-reflectivity mirror, c — laser with a resonator (full reflectivity mirror and a quartz plate)

Fig. 4 (a, b) presents lines of the constant energy of the pulse as a function of the power supply tension and nitrogen pressure (a — laser with mirror, b —with resonator). In case (b) a 2.5-fold increase in energy impulse occurs under optimal conditions.

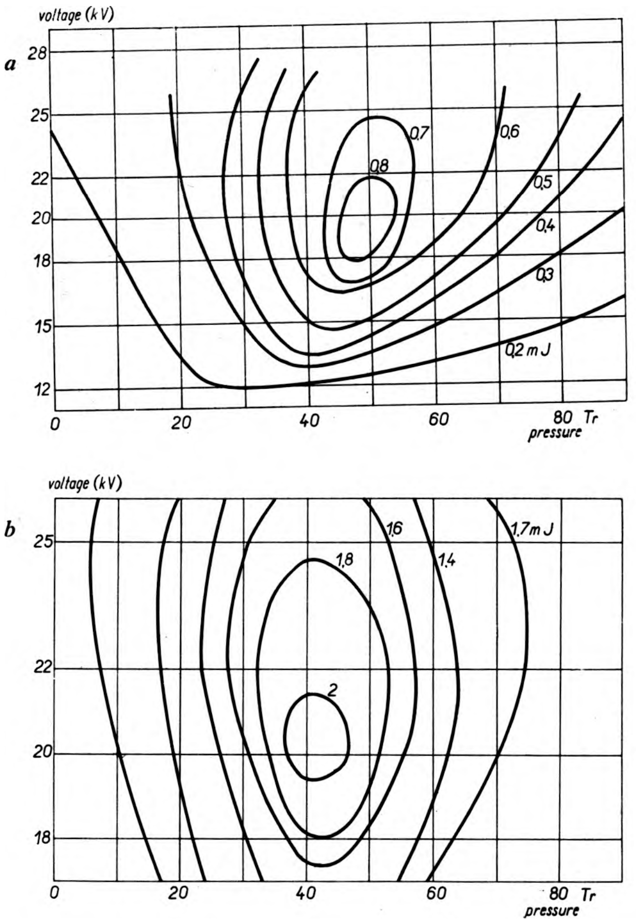

Fig. 4. Laser pulse energy vs. the power supply tension and nitrogen pressure:
a — laser with one mirror, b — laser with resonator

Fig. 5 (a, b) presents the dependence of laser power on the repetition rate at various power supply tensions. Case (a) refers to the laser without mirrors, case (b) to the laser with a single mirror. It appears that for the laser with one mirror the peak power is higher, especially at low tensions and high frequencies. At 18 kV and a frequency 40 Hz, the power increases three-fold due to the addition of one mirror.

Fig. 6 (a, b) presents the dependence of the pulse duration on pressure at various power supply tensions (a — laser with mirror, b — with resonator). The pulse duration (FWHM) increases with the pressure, it decreases as the tension increases, and is not influenced by the presence of either the resonator or single mirror. The pulse duration increases as the nitrogen pressure increases, in contrast with other types of lasers described in the literature (e.g. [10]). The laser pulse duration does not depend on the repetition frequency.

The optimal conditions for laser work at a 33 Hz repetition frequency are: nitrogen pressure 47 Tr, and power supply tension 23 kV. Under optimal conditions the laser constant — the ratio of the tension between channel electrodes to nitrogen pressure and the distance between electrodes — is equal to 120 V/cm·Tr.

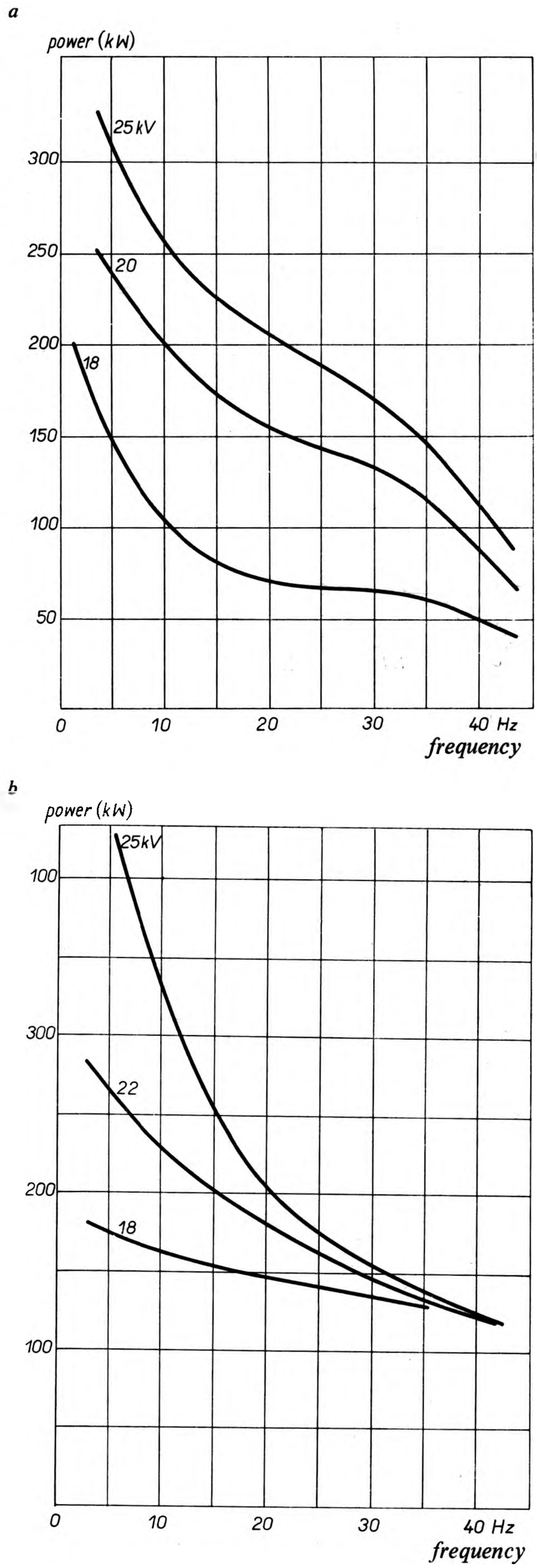

Fig. 5. Laser power vs. the laser repetition rate at various power supply tensions:
a — laser without mirrors, b — laser with one mirror

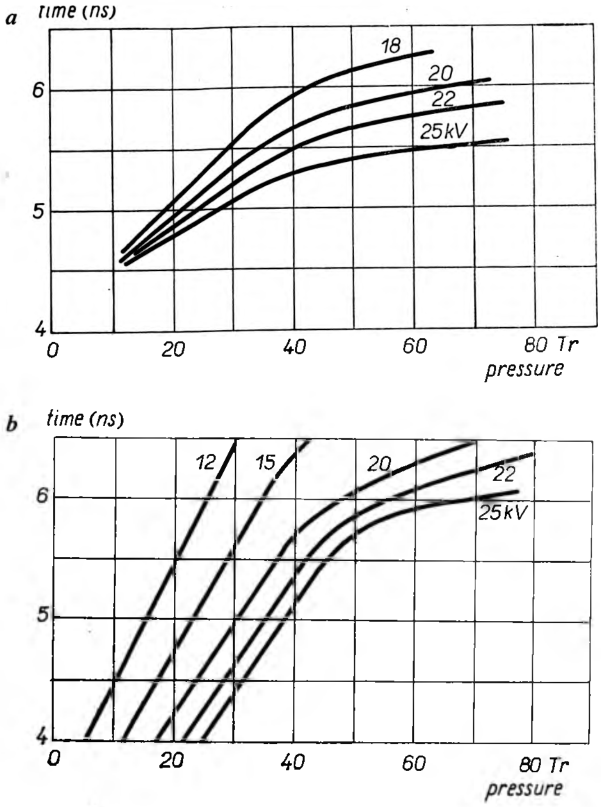

Fig. 6. Laser pulse duration (FWHM) vs. the nitrogen pressure at various power supply tensions:

a — laser with one mirror, b — laser with resonator

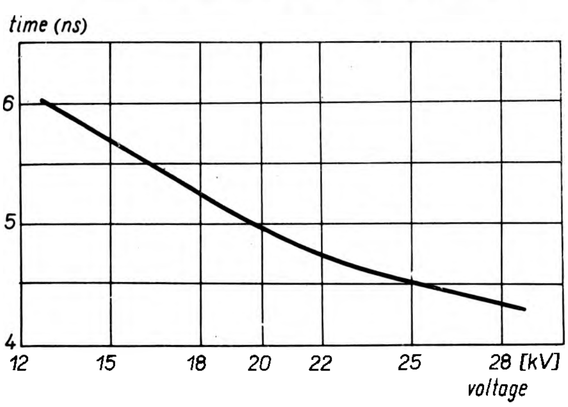

Fig. 7. Laser pulse duration vs. the power supply tension

The nitrogen laser beam is highly divergent. Since often only a part of the surface illuminated by the laser is to be utilized the distribution of radiation intensity in a cross-section of the beam must be known.

Studies of the beam were carried out in the following way: laser radiation was transmitted through a lens onto photographic paper. The distance of the lens from the window was chosen to obtain on the paper an image of the beam cross-section at the exit of the laser channel. The intensity of the radiation was regulated with the aid of two linear polarizers. The distribution of radiation intensity in the beam was studied in relation to the frequency of laser function.

The results obtained are presented in fig. 8. For low repetition frequencies the discharge in the channel is dispersed on the glass walls. Thus these parts of the channel radiate most intensely. For high repeti-

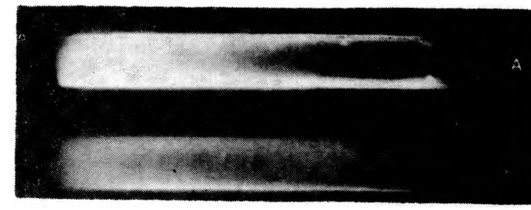

Fig. 8. Cross-section of the laser beam at the exit of the channel:

a — low repetition rate of the laser, b — high (>15 Hz) repetition rate of the laser

tion frequencies the light is almost homogeneous but distributed within the cross-section of the channel.

The construction of nitrogen laser is simple. The laser uses an inexpensive and easily available gas, it works at room temperature and yields easily repeatable pulses. It is a good pumping source for dye lasers working from ultraviolet up to near infrared. In many other applications, short pulse, high repetition frequency, and relatively high power are useful.

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Описание конструкции и параметров азотного лазера

В работе описан сконструированный простой лазер N_2. Полученная выходная мощность составляет 0,5 МВт, а продолжительность импульса FWHM — около 5 нс. Измерена зависимость пиковой мощности и продолжительность импульса лазера от напряжения питателя мощности, давления азота и частоты повторения импульса. Распределение плотности излучения в сечении лазерного пучка исследовалось в отнесении к частоте повторения импульса лазера.

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