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Electrooptical Switches

Schemes of electrooptic switches used as optical shutters of single nanosecond switching are presented. Special constructions of Kerr cells are shown. Pulse sources for Q-switches of laser resonators and switches shortening the laser pulses are shown.

1. Introduction

Electrooptical switches applied to generate short pulses of light have been known and used for quite a long time, among others in photography of rapid dynamic processes [1]. Light modulation methods by means of electrooptical switches (Kerr and Pockels cells) have, for several years, been undergoing a revival in connection with the development of the laser technique. They are applied to control an already generated beam of laser light as well as to produce short radiation pulses though modulating the quality factor of laser resonators.

In the first case, this may concern the plotting of information on the light wave amplitude (a typical amplitude modulation process) [2] or isolating of pulses of appropriate duration from another transient (100% modulation). The second case concerns the removing of losses produced by the electrooptical converter to the laser resonator (3). Systems applied here are similar to systems of 100% modulation.

Sets composed of an electrooptical switch (Kerr or Pockels cell) and a suitable generator controlling its action have been used in the two above mentioned systems.

The principal difficulty encountered in these arrangements consists in securing a change of the polarization state of laser radiation in space of time of one nanosecond order. This requires the utilization of high voltage (a dozen or more kV) controlling pulses of the same temporal rise (fall); it necessitates, moreover, very strict requirements as regards the construction of the switch.

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Certain arrangements used for Q-switching of laser resonators on a solid body and for pulse shaping behind the resonator (100% modulation) as well as for appropriate investigations are presented below. There are also solutions of the Kerr cells construction and feeding generators together preliminary elaborations on Pockels cells.

2. Modulation Sets and Investigation of these Sets

It is known that Kerr cells applied to Q-modulation of a resonator can operate in systems with removed or applied voltage. The case of applying quarter-wave voltage (after its transition through the cell there occurs a change of linear to circular polarization or vice-versa) is shown in Figs. 1a and 1b.

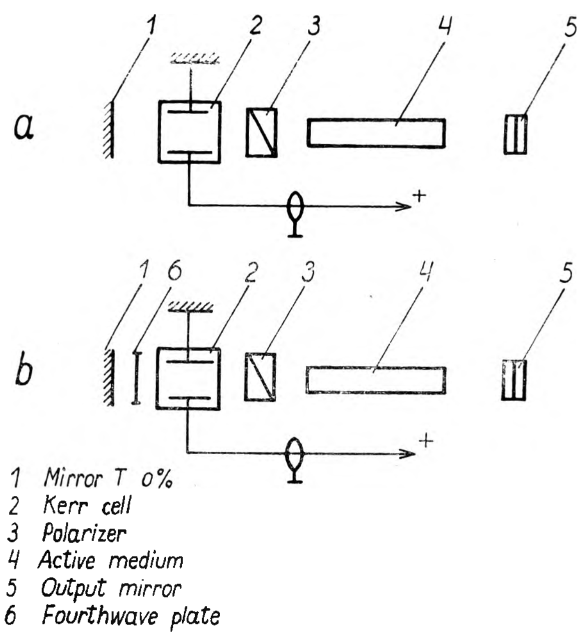

Fig. 1

The cutoff of losses occurs in these systems after voltage has been removed from the cell (Fig. 1a) or after it has been applied (Fig. 1b). The diagram of a generator controlling the operation of a Kerr cell by removing voltage is shown in Fig. 2.

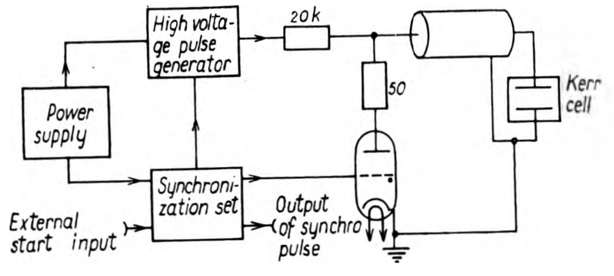

Fig. 2

The generator makes it possible to control the delay in shunting the thyratron in relation to the movement of switching high voltage on the cell and the ignition of the pumping lamp (Fig. 3).

Thyratron TG-1-11-1000/25 applied in this system allows to gain time for cell discharge of ca. 20 ns. This time suffices for the generation of laser radiation pulses of a tens of nanoseconds order.

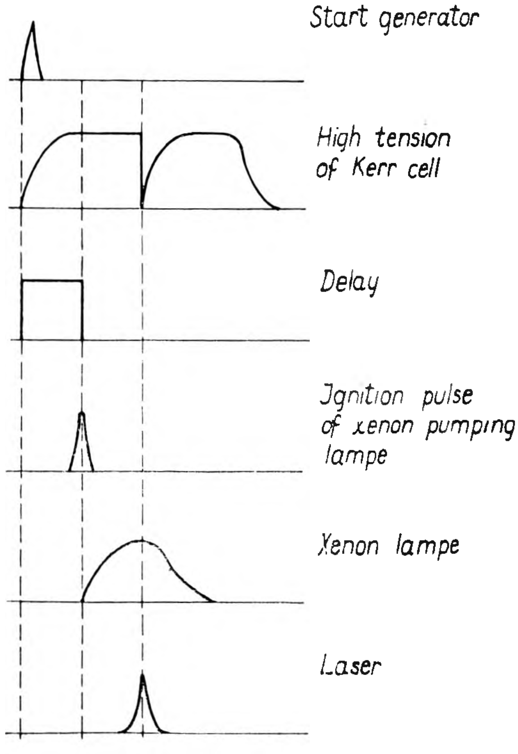

Fig. 3

The substitution of the thyratron by a high-pressure spark-gap makes it possible to cut down the shunting time to single nanoseconds. Despite the existence of thyratrons acting much quicker than the thyratron applied by the authors, spark-gap generators seem to be more prospective. They are of simple construction, sufficiently quick-acting and — what is of prime importance — they facilitate the shaping of short high-voltage pulses of very steep slopes. This is essential at the application of electrooptical switches as 100% modulators of light radiation.

In laser technique such systems are used for isolating a single pulse from a sequence generated in a system of self-locking of modes [4] and for additional shortening of the laser pulse [5].

Operational principles of such arrangement is shown in Fig. 4.

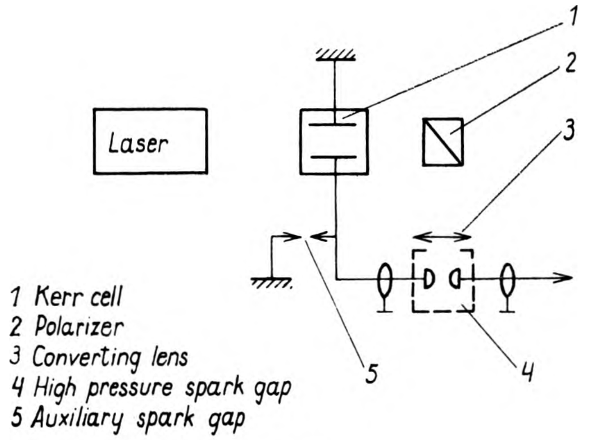

Fig. 4

In this case a rectangular pulse of half-wave voltage of required duration (in the case of isolating a single pulse from a sequence $\tau \leqslant T = \frac{2L}{C}$, where L — resonator length) should be applied to the Kerr cell.

Spark-gap ignition is controlled by issuing radiation concentrated on one of the electrodes by means of a lens.

A generator of this type has been investigated in accordance with the arrangement shown in Fig. 5.

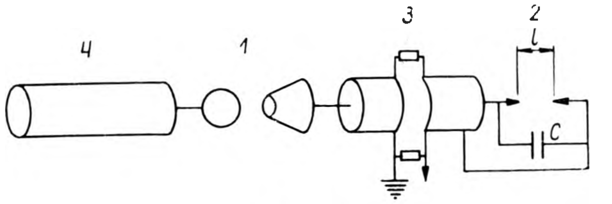

Fig. 5

The rise in the time of voltage pulses (according to operational conditions) and possibilities of regulating their duration have been examined.

Spark-gap–1 was filled with nitrogen at a pressure of 11.5 atm. Shunt–2 and capacitor C (simulating a Kerr cell) were placed in a cylindrical screen connected with the outer conductor of the cable.

The shape of the pulse on the load has been evalued on the basic of a measurement of the current flowing in a concentric line. To attain this a series of parallel connected low-value resistors have been inserted between two sections of the previously cut outer conductor of the cable [5] and the voltage drop on these resistors has been registered on an oscilloscope.

A resistor thus formed showed sufficient properties for an observation on pulses of increasing time of the order of tenths of a nanosecond.

Voltage pulses on capacitive load are presented as an example in Fig. 6. The distance between electrodes of an additional spark-gap are equal $l = 10$ mm (Fig. 6a) and $l = 7$ mm (Fig. 6b).

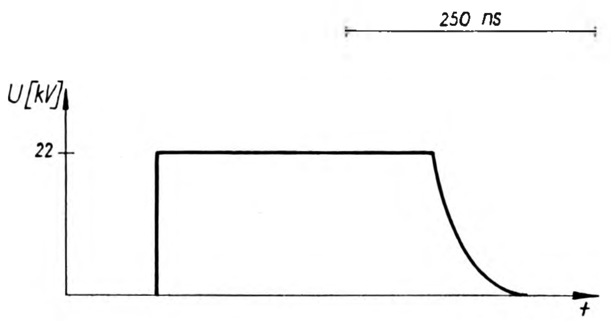

Fig. 6a

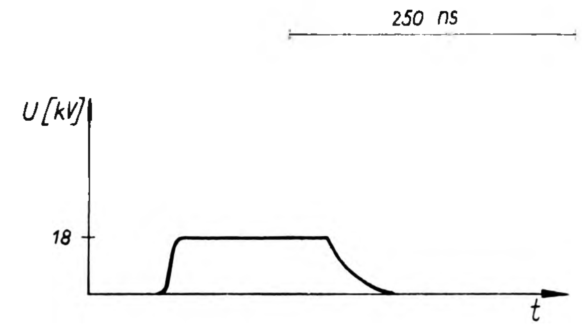

Fig. 6b

The time of pulse increase is inversely proportional to the pressure of gas in the spark-gap. For a pressure of 11.5 atm the time of pulse increase was ca. $\sim$0.6 ns. This gives decisive advantage of the pressure spark-gap over the thyratron.

Such arrangements (with an additional spark-gap) show stable operation when the pulse duration is above 20 ns.

For the generation of high-voltage pulses of shorter duration the arrangement presented in Fig. 7 may be utilized.

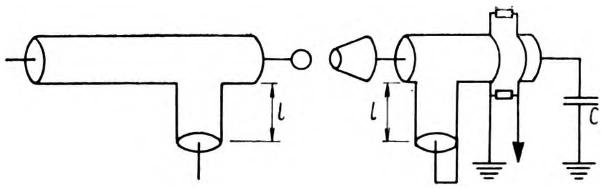

Fig. 7

An identical spark-gap filled with nitrogen of the same pressure has been applied here. The shape of the voltage pulse on the end of the line has been examined at capacity loads of different values. The shapes of voltage pulses are shown in Fig. 8.

Capacity C had in this case the following values: $C = 0$ (Fig. 8a), $C = 23$ pF (Fig. 8b) and $C = 100$ pF (Fig. 8c).

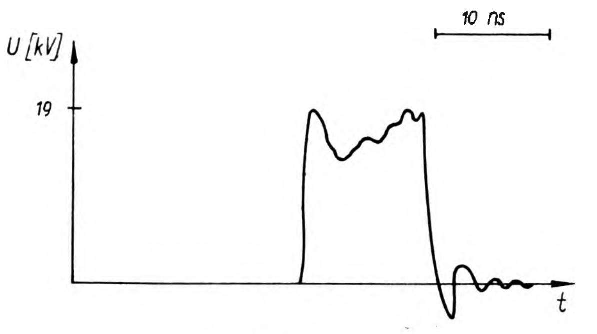

Fig. 8a

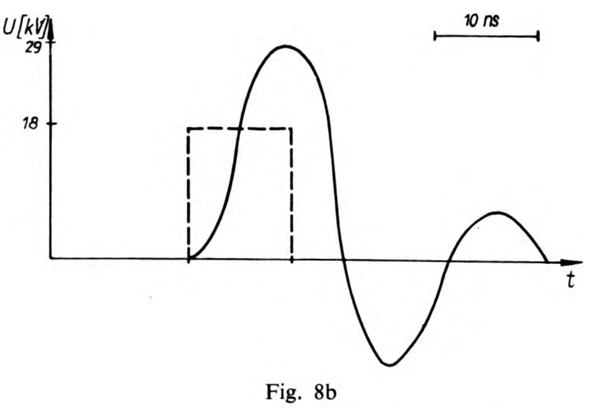

Fig. 8b

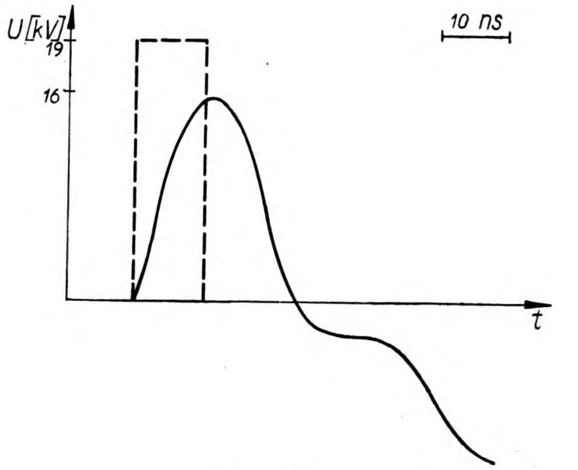

Fig. 8c

The shape of voltage pulse in the case of an open circuit is marked by a dotted line.

The investigations indicate that charging is of an oscillatory character.

Better matching for and considerably lower resonant effects in cells of new designs will be presented in a successive paper.

3. Designs and Investigations of Kerr and Pockels Cells

Several constructions of Kerr cells have been produced for an active Q-modulation. It has been found that principal problems concerned the selection of suitable materials and the production of a compact construction ensuring a pure capacitive load of the concentric line. Additional difficulties were caused by the high voltage at which these cells are utilized. In order to secure the correct operation of the cell at field strengths of 20 to 30 $kVcm^{-1}$ thoroughly purified nitrobenzene of a resistance above $10^{10}\Omega$ cm should be applied. This requires an appropriate technology

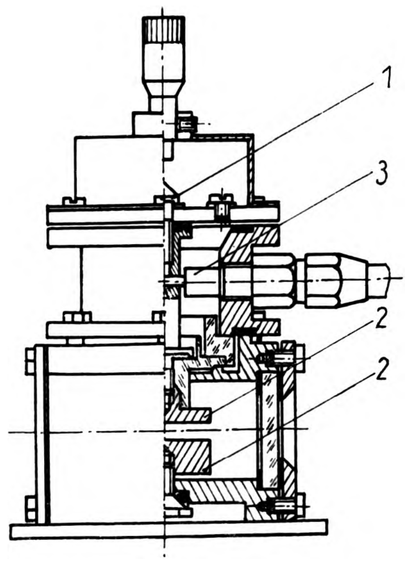

Fig. 10a

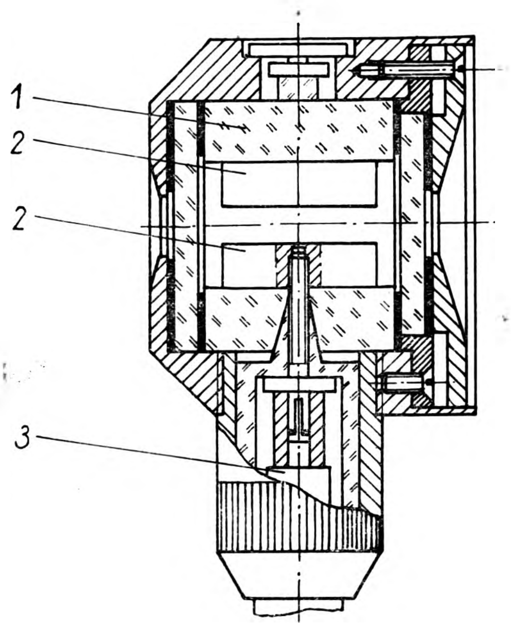

Fig. 9a

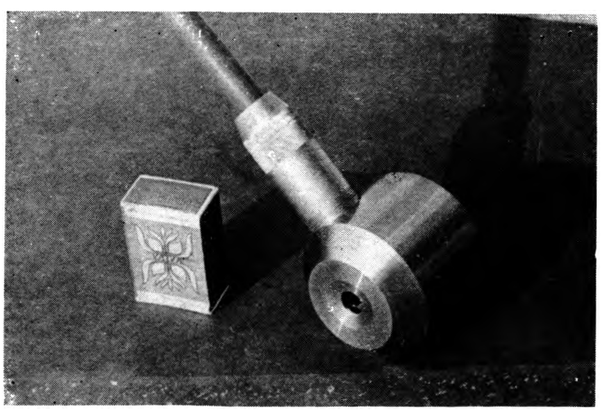

Fig. 9b

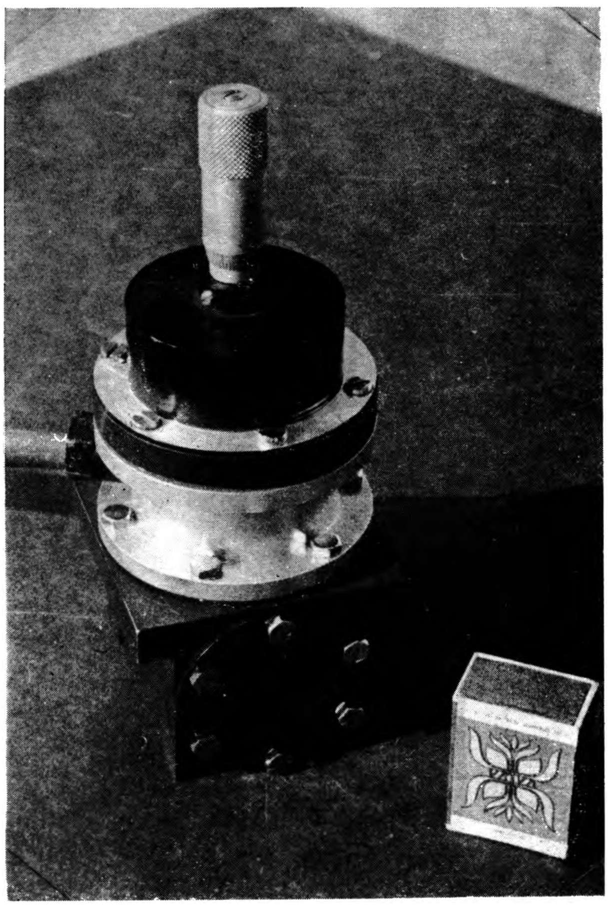

Fig. 10b

of purification, filling of the cell and suitable exploitation.

One of the versions of Kerr cells employment is shown in Fig. 9.

This cell is dismountable. The closing windows are pressed down by means of teflon rings to a glass housing where the electrodes have been placed. Electrodes made of stainless steel or nickel have been applied. The entire device is enclosed in a metallic screen.

The capacity of the cell equals 30 pF.

Another construction of the cell produced entirely of metal is presented in Fig. 10.

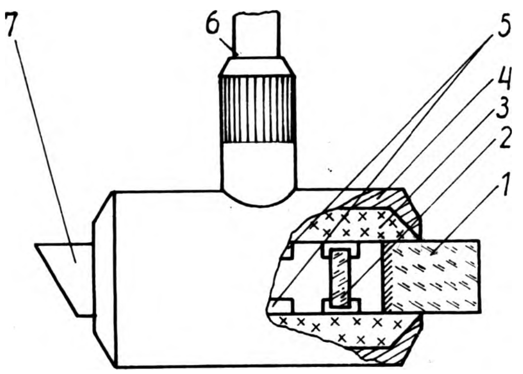

Fig. 11

An additional spark-gap has been placed in this cell. It can, therefore, operate in a system of e.g., isolating a single pulse from a sequence. This cell is also dismountable and the sealing of closing windows is similar to the previous construction. This cell is, unfortunately, of a higher capacity, (ca. 50 pF), the necessity of installing a spark-gap worsens, therefore, the heterogeneity of the terminal section of the line.

Static and dynamic breakdown tests of cells have been carried out, the effectiveness of changes in the polarization state has also been examined. Results thus obtained are in agreement with presuppositions.

An integrated modulator, comprising — in a common housing — a polarizer, a Kerr cell, a quarter-wave and an entirely reflecting mirror (Fig. 11), has also been elaborated for a monopulse generator.

This is an extremely convenient construction. The entire, adequately adjusted device, can be placed in holders of the kind commonly used for mounting mirrors.

Preliminary research works on the application of Pockels cells to modulation were also carried out.

A relatively simple construction is shown in Fig. 12.

A KDP crystal of dimensions $20 \times 20 \times 40$ mm, with the utilization of a longitudinal electrooptical effect has been used in this cell. Electrodes have been prepared by gold dusting, indium rollers ensured a good contact with the holder. This simple construction has been successfully tested as a system for the isolating of a pulse from a sequence generated in a self-locking system of modes.

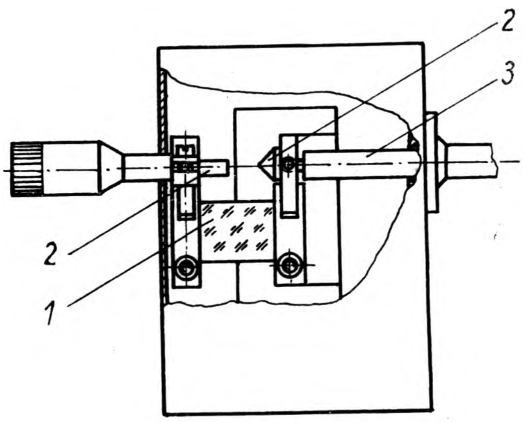

Fig. 12a

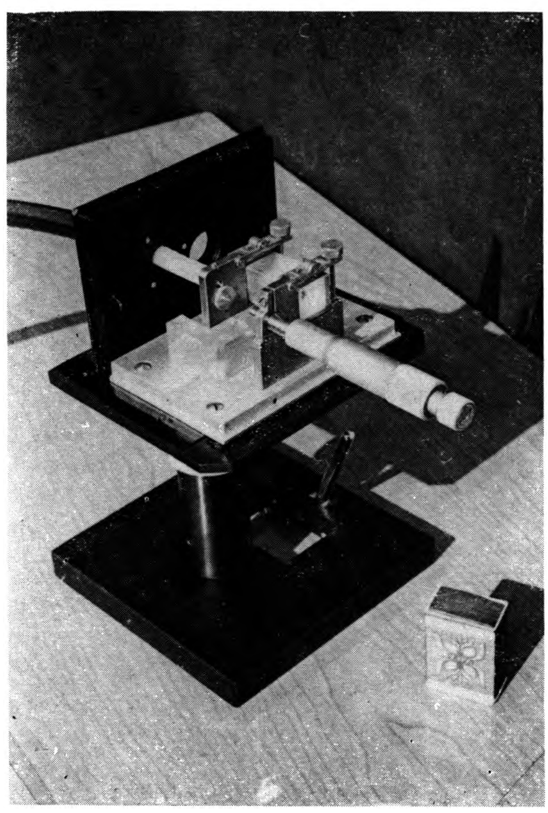

Fig. 12b

4. Conclusions

The constructed electronic and electrooptical elements made it possible to extend investigations concerning Q-switches of lasers on a solid body.

Laser generators with this modulation type of quality factor are much more stable in operation compared with arrangements with a rotating prism or nonlinear filters. They allow, moreover, to obtain considerably shorter pulses. A control of the rapid switching technique of laser radiation polarization opens, moreover, possibilities to apply them to more complicated laser systems generating pulses of a duration up to and including 1 ns.

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