FORMERS OF HIGH VOLTAGE RECTANGULAR IMPULSES FOR POWERFUL MICROWAVE DEVICES

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Abstract

The simple devices forming high-voltage rectangular pulses with weakly irregular tops, which are based on discharging capacitive energy storage to an active load via a corrective reactive LC-circuit with a built-in damping resistor, are considered. High-voltage pulse generators for high-power microwave devices, which were created at IAP and are operated in the range from single nanoseconds to 100 microseconds with amplitudes up to hundreds of kilovolts, are briefly reviewed.

INTRODUCTION

Studies of high-power relativistic and weakly relativistic microwave devices require generators that produce rectangular pulses with amplitudes ranging from tens to hundreds of kilovolts and durations from single nanoseconds to hundreds of microseconds. As a rule, in such cases, the irregularity of the pulse tops must not exceed 1–2%.

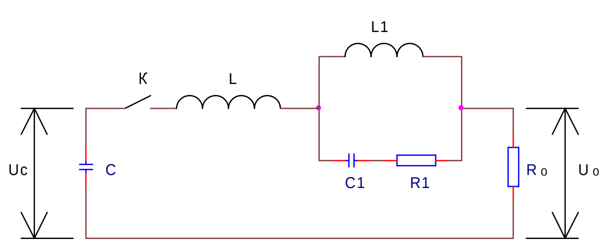

Fig. 1. Former of a pulse with a uniform top.

There are known devices using LC-circuits, which allow one to obtain pulses whose shape is close to the rectangular one. To ensure electric reliability and ease of manufacturing and tuning the device, the actual design of a high-voltage pulse former must contain only a few elements. However, the irregularity of the tops of the pulses formed by such circuits is 10%–15% when the number of LC-circuits is small. To obtain pulses, in which the instability of the tops does not exceed 1%–2%, the author proposed a simple shaping scheme [1] shown in Fig. 1. In this scheme, an active damping resistor R_1 is included in the capacitive circuit of the parallel oscillative circuit to suppress oscillations at the pulse top. The characteristic shape of the pulse at the former output is shown in Fig. 2.

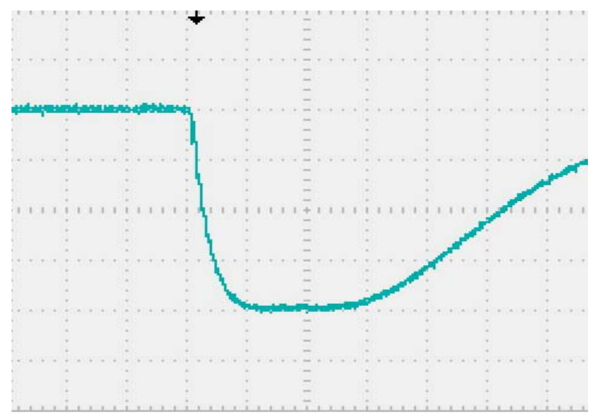

Fig. 2. Output pulse of the former.

The results of the calculations and experiments with the prototype of the former showed that it suffices to use one additional resonance circuit to obtain the pulses satisfying the specified requirements. The former was calculated from the set values of the pulse top duration, pulse amplitude, and load resistance was performed by the formulas given in [1], which were found by minimizing the irregularity of the pulse top.

FORMER FOR A NANOSECOND ELECTRON ACCELERATOR

This scheme was used to design a small-size nanosecond electron accelerator generating pulses with an energy of 150 keV and a duration of about 20 ns [2]. The energy storage of the accelerator is a coaxial capacitor having a capacity of 150 pF. The feasibility of using such an energy storage for this case was rationalized in [1]. The corrective circuit of the former is also structured coaxially, as shown in Fig. 3. The general view of the corrective circuit is shown in Fig. 4. Energy losses in the damping resistor R_1 do not exceed 2% of the energy stored in the capacitor C, and the voltage at the elements of the corrective circuit does not exceed 20% of that value. This allowed minimizing the size of the former, which is rather important for the devices operating in the nanosecond range.

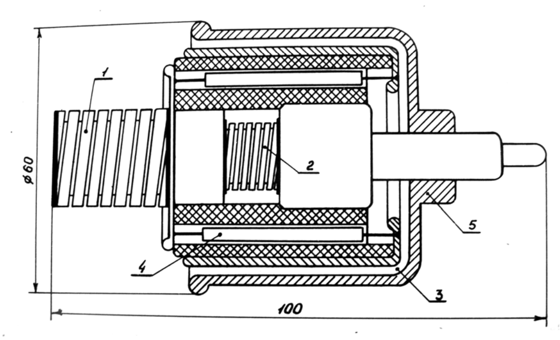

Fig. 3. Corrective circuit: 1 – inductance L, 2 – inductance L1, 3 – capacitor C1, 4 – resistors R1, 5 – external electrode of C1.

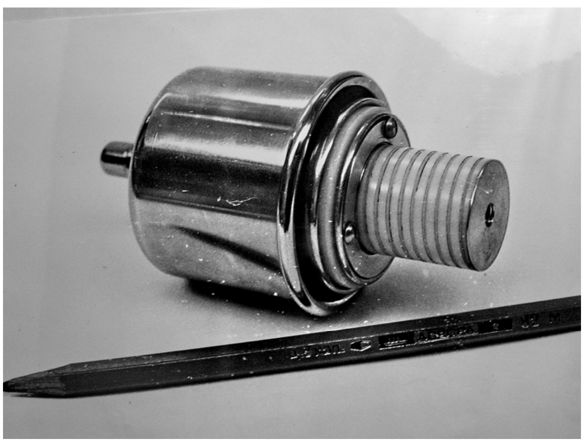

Fig. 4. General view of the corrective circuit.

The total length of the accelerator is about 500 mm. The oscillogram of the voltage at the accelerator cathode is shown in Fig. 5.

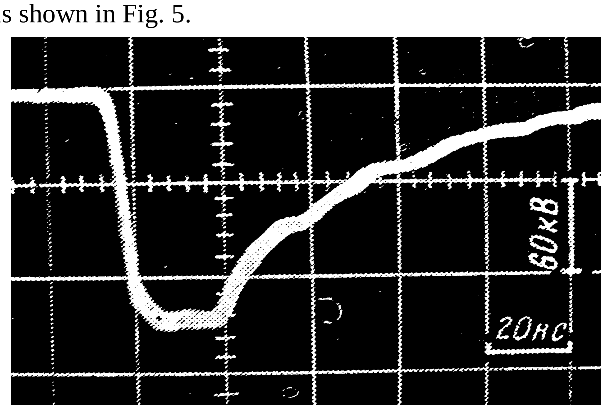

Fig. 5. Voltage pulse at the accelerator cathode.

Application of this generation scheme is especially efficient in the nanosecond range, where the value of the stray inductance of the discharge circuit is comparable with the value of inductance L and can be compensated by decreasing it without increasing additionally the duration of the pulse front.

FORMERS OF MICROSECOND PULSES

A drawback of the above-described generation scheme is that the duration of the front of the generated pulse is about 30% of the duration of the uniform section of the top. In the microsecond range, it becomes possible to reduce the duration of the pulse front. One of the generator schemes using the sharpening of the pulse front is shown in Fig. 6.

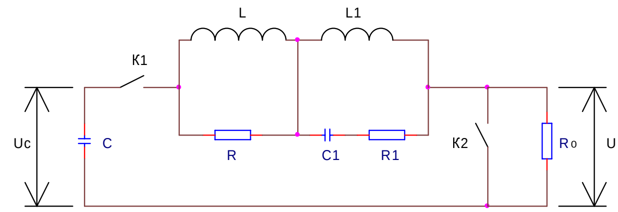

Fig. 6. Former of pulses with front sharpening.

To sharpen the pulse front, this scheme uses shunting of the forming inductance L by the active resistor R. In this case, the duration of the output pulse front is determined by only the time of switching of the switch K_1 and the value of the stray inductance of the discharge circuit. The oscillogram of the pulses generated by this scheme is shown in Fig. 7.

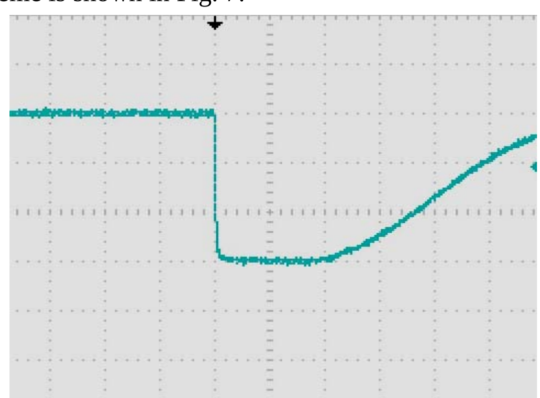

Fig. 7. Output pulse of the former with front sharpening.

The formulas for the calculation of the former elements are given in [3]. The additional switch K2 is used to shorten the pulse edge. It is possible to use partially controlled switches in this scheme, e.g., gas discharges, thyratrons, and thyristors, which should be regarded as a merit of this scheme. The energy stored in the capacitor C is small as compared with the schemes using partial discharges of the storage, which makes this former safer in the case of the breakdown of the main switch in a microwave device. Moreover, the load protection function can be assigned to the chopping switch K2. Despite the fact that up to 30% of the energy stored in the storage C can be released in the shunting resistor R, the use of such generation schemes is efficient for high-voltage pulse generators producing average powers up to single kilowatts, which is characteristic of many problems of the research in the field of microwave electronics.

GENERATORS OF MICROSECOND PULSES

The combination of the proposed shaping scheme and the Marx generator was used by the IAP team to design a microsecond electron accelerator with a thermionic cathode, which was used to study relativistic carsinotrons with a beam energy of 300 keV, a current of up to 300 A, and a pulse duration of 10 µs [4].

A pulse-periodic generator with a duration of the pulse top of about 1 µs, an amplitude of up to 23 kV, and a current of up to 5 kA was implemented for a pulse repetition rate of up to 10 Hz to be used in development of high-power gyroklystrons [5]. In combination with a step-up pulse transformer, it makes it possible to obtain pulses with an amplitude up to 500 kV and a current of up to 200 A. As the switch K1, we used the new-generation TPI1–10k/50 thyratron which allows switching currents of up to 10 kA in tens of nanoseconds.

An example of using the proposed pulse shaping scheme can be the series of small-size modulators for magnetrons operating in the range from 0.1 to 10 µs and producing output pulses with amplitudes of up to 30 kV. One of such devices is described in [6].

The most recent development using the former of this type is the pulse-periodic modulator for gyroklystrons. The output pulses of the modulator are as follows: the pulse amplitude is up to 80 kV, the current is up to 40 A, the pulse top duration is 100 µs, and the irregularity of the top is 1%. The oscillogram of the modulator output pulse is shown in Fig. 8. The general view of the modulator is given in Fig. 9.

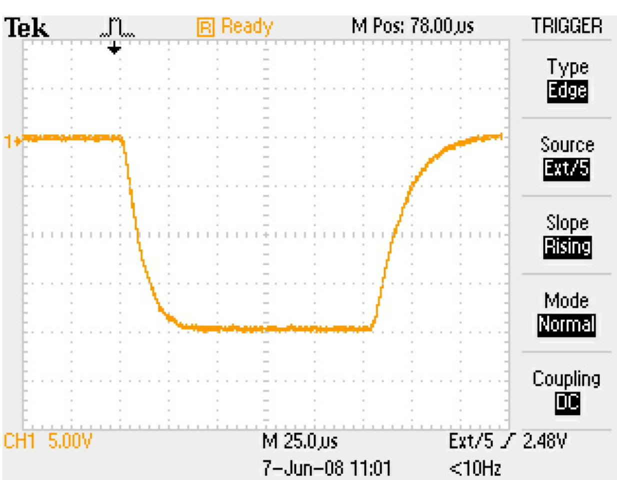

Fig. 8. Output pulse of the M80/40/100 modulator

Fig. 9. General view of the M80/40/100 modulator.

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