COMPACT LOW-IMPEDANCE HIGH-CURRENT ACCELERATOR

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Development of relativistic high-frequency electronics posed a number of problems yet remained unsolved. One of them is creating powerful and comparatively compact generators of electromagnetic radiation. In this way great progress is achieved with the use of small accelerators [1] generating millimeter-band oscillations of power up to 40 MW. However, these systems, as with many other devices containing high-current accelerators, have the proper microwave generator sizes significantly smaller than other units composing the high-current accelerator. Therefore, generators of power from 10^8 to 10^{10} W should be very awkward. One of the ways to overcome the problem is to employ schemes including a high-current low-impedance accelerator and a microwave generator with the spatially developed electrodynamic structure [2]. Note, that such studies are also promising for applications, since high-current electron beams at moderate voltages are produced there in the simplest way.

A diagram of the developed setup is shown in Fig. 1.

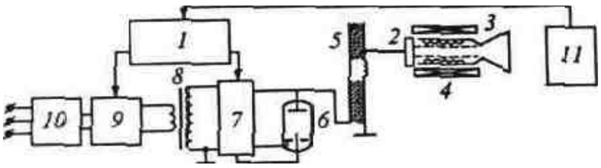

Fig. 1. Diagram of the experimental setup: control unit (1), circular diode with magnetic insulation (2), electrodynamic structures (3), superconducting solenoid (4), double shaping line (5), multichannel discharger (6), high-voltage rectifier (7), high-voltage transformer (8), thyristor inverter (9), supply rectifier (10), and output beam control unit (11).

The compact low-impedance accelerator consists of an intermediate storage unit (strip shaping line with a mylar insulator), line commutator (10-channel gas discharger), cathode unit, beam transport channel, collector, and output horn with a window transparent for microwaves. A magnetic field for the diode with magnetic insulation is induced by a superconducting solenoid with inductance of 40 kG, length about 50 cm, and inner diameter of 20 cm. The accelerator high-voltage system including the shaping line, a rectifier for its charging, and a commutator are placed into a case filled with castor oil. A control unit furnishes functioning and interaction of all the setup systems and units, as well as measures the most important parameters including the output radiation. The thyristor unit of the charging device and the power rectifier transform the three-phase supply voltage into a more high-frequency one that is used to feed the line which is charged up to about 200 kV via a high-voltage transformer. After charging, the control unit turns on the multichannel discharger and the line forms an accelerating voltage pulse of duration about 10^{-8} s at the diode.

Let us consider the operation of the most important components in more detail. The voltage pulse is formed by the strip storage line with solid insulation and high specific characteristics. The high-current diode and line impedances are approximately the same, Fig. 2, $\rho_1 = U_1/I_1 \cong 2\Omega$.

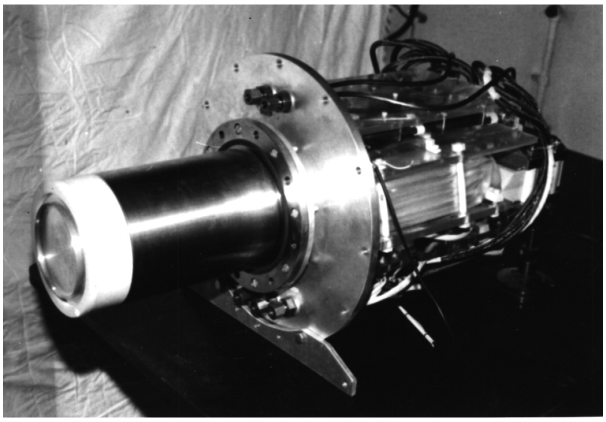

Fig. 2. Photography of cathode unit.

The strip line has a film insulation and an operating field of about 100 kV/mm. Since the linewidth is limited, two lines connected in parallel are used. The Blumeline circuit used to furnish an output voltage equal to the charging one thus presents the system of four parallel-series strip lines in a single stack. As an insulator, we chose mylar with ε= 3.2 and a breakdown field of about 150 kV/mm. The insulation is formed by 20 layers 0.09 mm thick. The static breakdown voltage for the line is not lower than 230 kV. To prevent external shorts and partial discharges, the line is immersed into oil. The linewidth is $d = 377\delta/\sqrt{\varepsilon}\,\rho_1 = 19$ cm (δ is the insulation thickness), the linelength l is controlled by the shaped pulse duration $\tau_p = 2l\sqrt{\varepsilon}/c$, where c is the speed of light; thus l = 1.3m at $\tau_p \cong 15$ ns.

One sees from Figure 1 that the high-voltage pulse is shaped by the diode after closing the commutator. Very strong requirements are imposed upon the latter: the commuted current is about 100 kA, voltage 200 kV, triggering time about 1 ns, resistance below 1 Ω in the open state, and inductance below 1 nH. These requirements can be satisfied only by using a multichannel controlled high-pressure gas discharger and special additional forcing of channel triggers.

To commute the two long strip lines connected in parallel, we developed a special plane 10-channel discharger with two working volumes. The discharge is ignited by combining three techniques: the trigatron method, field distortion, and pulsed UV illumination ones. The choice of the number of channels is controlled by the discharger inductance and the electrode erosion limit per a single discharge to maintain multiple actuations (frequency mode) with no noticeable drift of parameters. The latter condition limits the electric discharge passing through the channel per pulse by a value of (1÷8)$10^{-4}C$.

To decrease the channel inductance and increase the triggering speed, the discharger was insulated by nitrogen at an operating pressure of 18 atm. The discharger interelectrode spacing was 6 mm. The independent shaping circuits of trigger pulses for every channel could actuate simultaneously all the ten channels. The multichannel discharger operation was provided by fitting a pressure, at which the line charging voltage is 90% of the discharger self-breakdown voltage.

The rectifier unit of the high-voltage system charges the line by a sequence of low-power pulses, having no need to demagnetize the transformer core and to use special thyristors. As the high-voltage valves, SDL-04-1300 columns are used with an operating voltage of 130 kV in series by pairs in the doubler circuit. As a charging pulse source of the primary circuit, a series of two-phase inverter with thyristors of intermediate power is fed immediately by the supply Larionov's rectifier. The line is charged by 50 bipolar pulses. The same pulse sequence charges storage units of the discharger multichannel trigger circuit. The pulsed toroidal transformer has a steel core and is immersed into oil together with other high-voltage components.

Tests of the multipulse charging circuit show its significant advantages over the single-pulse one. The charging unit operative load is substantially reduced and its control is simplified. The process is optimized by charging pulses' duration, number, and repetition rate. Passive components' parameters of the charging circuit are fitted to the thyristors' operation in the optimum charging mode, when these are reliably blocked with the shortest protection interval between pulses.

Fig. 3 displays the oscillograms of charging pulses fed to the transformer primary winding and of the voltage at charged and commuted line (t_p is the discharger actuation time).

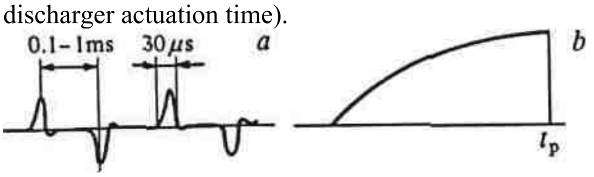

Fig. 3. Oscillograms of charging pulses at the transformer primary winding (a) and the shaping line (b).

Currently, the accelerator produces a required tabular electron beam 130-150 mm dia at voltage of 200 kV and current up to 20 kA. The later can be increased up to 100 kA. As a coherent radiation source, a multiwave millimeter-band Cherenkov oscillator is developed. The high-current accelerator with the microwave oscillator represents a cylinder about 40 cm dia and 1.5 m long. Photography of this accelerator is shown on Fig. 4. Its weight is approximately 200 kg, the total setup weight including the solenoid does not exceed 500 kg. The setup operates at the repetition rate from 1 to 100 Hz.

Experiments carried out up to now show the accelerator to produce powerful coherent radiation in the millimeter band. Microwave generators used in the setup have some properties to be discussed elsewhere.

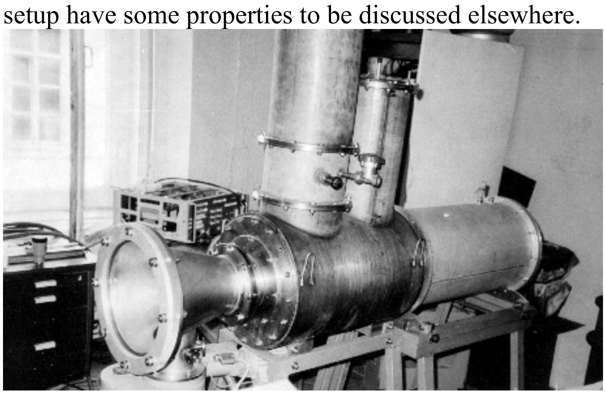

Fig. 4. Photography of compact accelerator with superconducting solenoid.

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