INVESTIGATION OF THE OPERATION OF A TWO-STAGE ACCELERATOR WITH AN ANODE LAYER WITH ONE ELECTRICAL POWER SUPPLY

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The two-stage accelerator with an anode layer, which has high acceleration efficiency, has a fairly complex electrical supply system, consisting of two independent power supplies [1-4]. This complex power supply limits the range of application of these accelerators. In the present paper we describe the results of an investigation of the operation of a two-stage accelerator with an anode layer with a simplified electrical power supply containing one source and an RC-divider. In Fig. 1, where 1 is the anode vapor distributor, 2 are the first-stage cathodes, 3 are the second-stage cathodes — the screens of the magnetic pole pieces, and 4 is a current receiver. We show the electrical power supply both with two (Fig. 1a), and with one supply source (Fig. 1b). In the circuit with one source, the potential difference between the anode-vapor distributor and the cathodes of the first stage (U_p) is maintained using a divider and is stabilized with a capacitance. The stabilization is necessary since current ripple occurs on the electrodes, which may lead to considerable oscillations of the voltage U_p, degradation of the characteristics, and to a change in the modes of operation of the accelerator [2].

We can make an approximate estimate of the parameters of the divider R_d and C_d, which will ensure that the accelerator operates efficiently, from the following expressions:

$$R_d \simeq U_p/(I_e(U_p) - I_i(U_p)); \quad (1)$$

$$C_d \geqslant \Delta I_p/\Delta U_p f, \quad (2)$$

where $I_e(U_p)$, $I_i(U_p)$ are the electron and ion currents to the cathodes of the first stage, determined experimentally, ΔI_p and f are the amplitude and frequency of the current ripple in the discharge, and ΔU_p is the greatest amplitude of the ripples of the discharge voltage, for which effective acceleration is preserved. The values of U_p and ΔU_p must satisfy the relation

$$U_p + \Delta U_p \leqslant U_{p\max},\ U_p - \Delta U_p \geqslant U_{p\min}, \quad (3)$$

where U_{pmax} and U_{pmin} are the upper and lower limits of the discharge voltage which ensure effective accelerator operation [3].

Experiments with the simplified power supply shown in Fig. 1b were carried out using a model of the two-stage accelerator described in [3]. We used bismuth as the working material. The electrical power supply was a three-phase bridge rectifier with voltage ripples of $\leqslant 6\%$, which was shunted by a capacitance C_2 = 150 μF, and a ballast resistance R_{b2} = 50 Ω, was connected in its circuit in order to limit the current in the case of a short-circuit and breakdown. This source was also used in the circuit with two power supplies (Fig. 1a) for the accelerating stage. A similar bridge rectifier shunted with a capacitance C_1 = 2 μF with a ballast resistance R_{b1} = 20 Ω was connected in the first (discharge) stage. For this model the parameters of the divider R_d and C_d obtained from Eqs. (1)-(3) were as follows: $R_d \geqslant 100$ Ω, $C_d \gtrsim 1$ μF for $I_e - I_i \leqslant 1$ A, $U_p \simeq 100$-150 V, $\Delta I_p/I_p \simeq 5 \cdot 10^{-2}$, $I_p \simeq 5$ A, $f \simeq 20$ kHz, $U_{pmax} \simeq 250$ V, $U_{pmin} \simeq 100$ V. The following values of the parameters R_d and C_d were tried: C_d = 0-18 μF, and $R_d = 60$-$2 \cdot 10^4$ Ω ($2 \cdot 10^4$ Ω is the resistance of the measuring circuits and insulators).

In the experiments we measured the current and voltage of the accelerating and discharge stages (I_a, U_a, I_p, U_p) in the circuit with two electrical power supplies, the total current and voltage of the accelerator (I_{ts}, U_{ts}) in the circuit with the divider, and also

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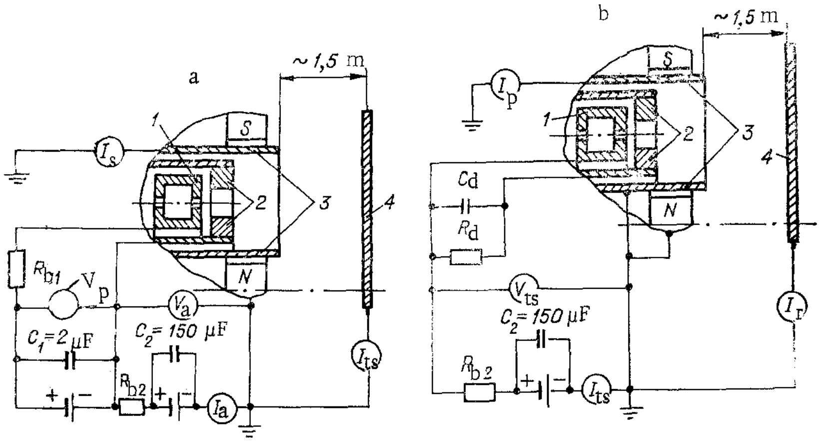

Fig. 1

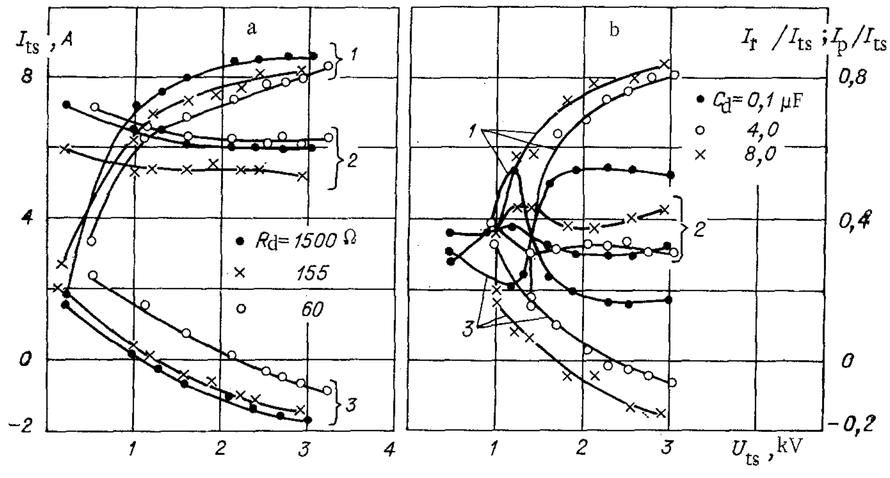

Fig. 2

the current at the poles (I_p) and the current at the receiver (I_r) — the ion current of the beam in both circuits.

In Fig. 2 (curve 1 is I_r/I_{ts}, curve 2 is I_{ts}, curve 3 is I_t/I_{ts}, the magnetic field strength in the working gap of the accelerator $H = 160 \cdot 10^3$ A/m, and the pressure in the vacuum chamber $p = (1.3\text{-}6.7) \cdot 10^{-5}$ GPa) we show characteristic current–voltage curves of the two-stage accelerator with one electrical power supply for a fixed capacitance $C_d = 4$ μF and different resistances (Fig. 2a), and for a fixed value of the divider resistance $R_d = 155$ Ω and different capacitances (Fig. 2b). As investigations showed, a change in the capacitance in the range $C_d = 2\text{-}18$ μF keeping $R_d \geqslant 60$ Ω unchanged does not lead to any appreciable change in the characteristics (Fig. 2b).

The accelerator mode of operation was obtained for all values of $C_d \geqslant 2$ μF and different combinations of R_d, C_d ($R_d = 60\text{-}2 \cdot 10^4$ Ω, and $C_d = 2\text{-}18$ μF).

In the range of capacitances $C_d = 0\text{-}2$ μF and different divider resistances R_d we could not obtain the accelerator mode (Fig. 2b).

Comparison of the characteristics of accelerators with the same geometrical dimensions and operating with two sources (Fig. 3, curve 1) and with one source (Fig. 3, curve 2) showed that the main parameters of the accelerator, namely, I_a and I_{ts}, I_r/I_a and I_r/I_{ts}, I_t/I_a and I_t/I_{ts} are practically the same when $C_d \geqslant 2$ μF. In this case the energy efficiency of the accelerator, defined as the ratio of the calorimeter power of the beam arriving at the receiver, to the total power fed to the discharge when operating with both circuits for a current ratio I_r/I_a, $I_r/I_{ts} \simeq 0.7\text{-}0.9$, was 0.6-0.7 for voltages U_{ts}, $U_a = 1.3$ kV and currents I_{ts}, $I_a = 5\text{-}7$ A. The accuracy with which the energy efficiency was measured was 10%.

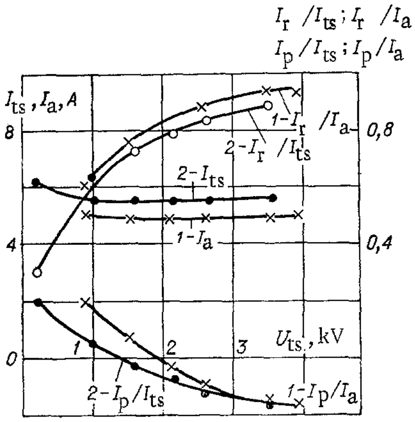

Fig. 3

When C_d < 2 μF the accelerator characteristics in the circuit with the divider differ considerably from the characteristics of the accelerator with two electrical power supplies, and the energy efficiency falls sharply (∿0.3).

The power dissipated in the resistance in the circuits with one power supply is small and is in the region of 1 W for $R_d = 2\cdot10^4$ Ω to 200 W for R_d = 60 Ω (U_d = 100-150 V, U_{ts} = 1.3 kV, and I_{ts} = 3-7 A).

Hence, the above experiments show that it is possible to operate a two-stage accelerator with an anode layer using one electrical power supply and an RC-divider with practically no change in the main accelerator characteristics.

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