FORMING ELECTRON BEAM PULSES OF A SUBNANOSECOND DURATION

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Production of high-intensity electron beams is connected with using considerable magnetic fields for the beam cross-sectional dimension maintaining. In this case it is possible to use the beam drift in crossed electric and magnetic fields for producing nano- and subnanosecond duration beams. In [2, 6] the method for production of electron beam current pulses of this duration using the above-mentioned effect is described.

The method [2,7] consists in that the time dependence of the particle energy is introduced into the electron beam during the beam current pulse. After that the beam separation based on particle energy and particle extraction in the energy range corresponding to the required pulse duration takes place. The beam particle energy dependence on time is produced by beam passing through the electric field E which is growing or falling during the time:

$$T=\tau*e*E*d/\Delta\varepsilon,$$

where: τ – the required duration of the electron beam current pulse; e – electron charge; d – beam path length in the electric field, $\Delta\varepsilon$ – energy range in which the particle extraction is carried out. Low-duration beam production is realized with the help of the energy separator, where $\Delta U/U$ is the separator energy resolution. The sharp dependence of beam particle energy on time can be produced in a different ways. For this purpose magnetron guns with secondary-emission cathodes can be used in which the voltage drop has a fast phase. Accordingly, the electron beam particle energies are of about several nanoseconds [6] while the beam currents are tens of amperes during the beam generation. It is possible also to use the shorting discharger with a commutation time of 2…10 ns during producing heavy-current beams (for example [1]).

For high-intensity beam separators the energy resolution is limited mostly by space charge forces. The separator with crossed fields [5] is free of this disadvantage and possesses a longitudinal and transverse dispersion. It is convenient to resolve the motion equation in crossed fields and to calculate space charge forces in a moving reference system, in which the electric field goes to zero and the task is reduced to the well-studied motion in a magnetic field [3, 5]. The space charge can be neglected at currents ~ 10 A, and to increase the beam current it is necessary to increase the magnetic and electric fields. Also the vacuum beam blanking is connected with the space charge presence [4]. In case of low beam ripples in a cylindrical chamber of a real size and particle energy being 50…100 keV the cut-off current of the vacuum blanking is ~ 100 A. So, the amperage does not exceed several tens of amperes in the separator with crossed fields and is limited by the vacuum breakdown between separator plates.

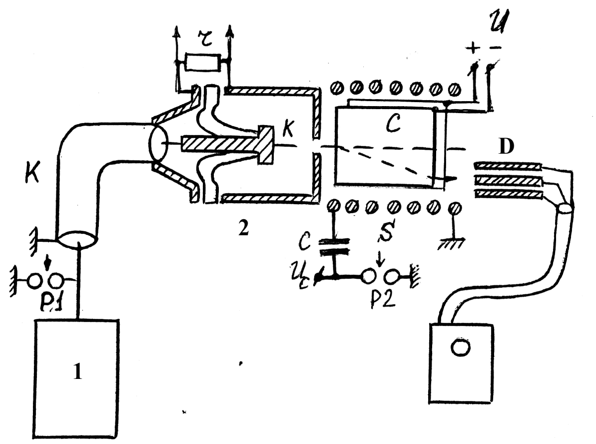

Fig. 1.

Energy particle separation can be carried out with the help of either magnetic or electric fields of deflector plates to which the nanosecond pulse generator is connected with the pulse rise time ~ 1 ns. In the first case these plates are connected at the end, in the second case they are open-ended. It is the second case which is interesting, when the deflector plates play the role of delay line capacitance. In this case the rate of voltage pulse propagation is selected to be equal to electron velocity and each of the beam particles will be situated in one transverse electric field during its motion. Within the duration of voltage pulse the electric field strength increases gradually which results in electron trajectory change. It is possible to extract electrons with a specified energy spread, and accordingly, to form the electron bunch of a low duration by placing the collimator at plate outputs.

The minimum possible duration of the produced beams is limited by the beam selfrepulsion and increasing its size and divergence, by the influence of beam finite size and the hole for its exit. Considering the pointed limits it is practically possible to produce electron beams of about tens of nanoseconds.

For checking out the main points of the method [1] we made a separator with crossed fields which produces a beam current of 4 A (see Fig. 1). The electron beam was formed in the heavy-current electron gun 2 with a blasting cathode [1], the beam particle energy dependence on time being formed with the help of voltage pulse shortening out with the shorting discharger P1 placed in liquid nitrogen. Marx generator 1 with high-voltage pulse up to 100 kV and duration up to 400 ns served as a power supply of the blasting cathode. The magnetic field was formed by a pulse solenoid S with an inhomogenity of ~10% on the beam trajectory. The electric field was formed by the parallel-sided plates C to which a direct voltage up to 30 kV was applied. The beam current at the exit was measured with the help of the measuring line D with a wave impedance of 50 Ohms and a transient time of ~0.2 ns. The dividers on the resistors served for measuring the cathode voltage and beam current. The separator had E≤ 30 kV/cm, H≤3 kOe, design resolution ~30%. The beam current **I** and cathode voltage **U** are shown in Fig. 2. The voltage decreasing duration was ~60 ns. Current and voltage splashes are caused by blasting cathode plasma instability. The current pulse duration $\mathbf{I_B}$ at the exit is ~5 ns at the half-height, the current peak value is 4 A.

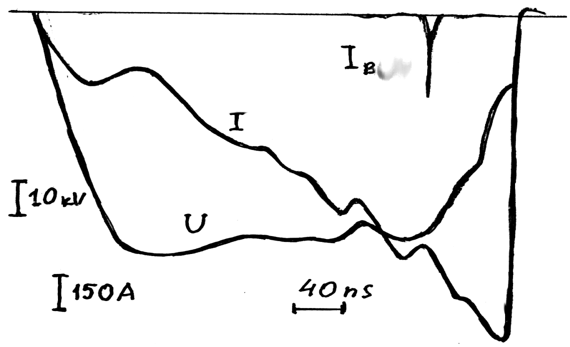

Fig. 2.

Using the methods of electron beam pulse production in crossed fields one can produce subnanosecond duration beams**.** Electron separators with crossed fields of a real size and real fields have an energy resolution of several of several percent, while beam currents being several tens of amperes. The main points of the method of second and nanosecond pulse beam production were proved by experiments.

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