July 6, 1965 W. OPITZ 3,193,722

METHOD AND MEANS FOR CONTROL OF A PULSED BEAM OF CHARGE CARRIERS

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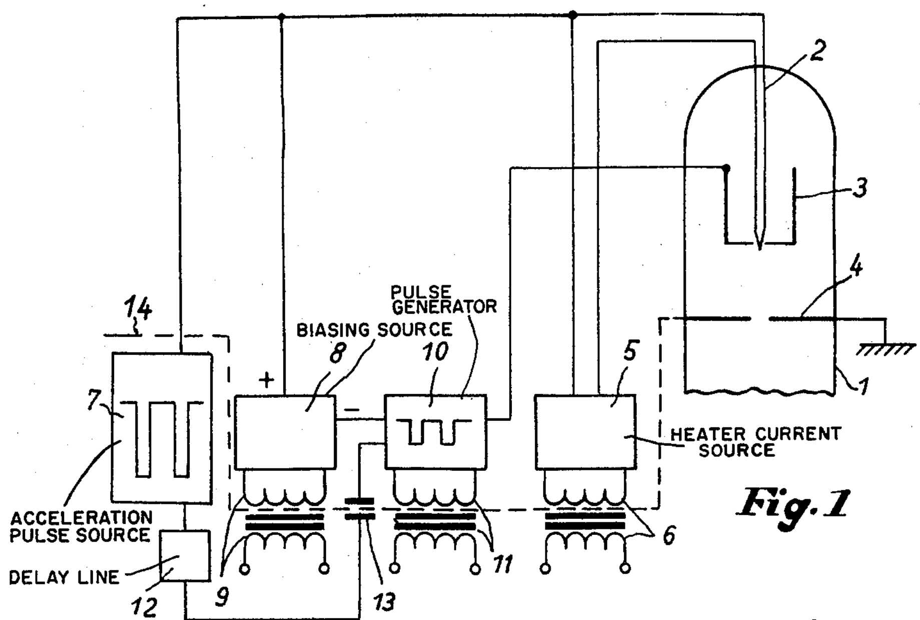

Fig. 1

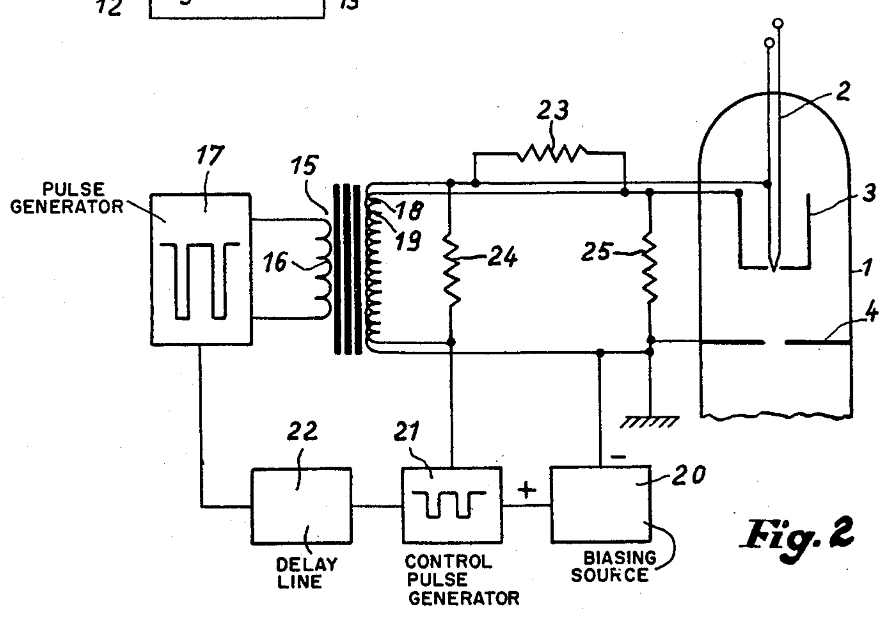

Fig. 2

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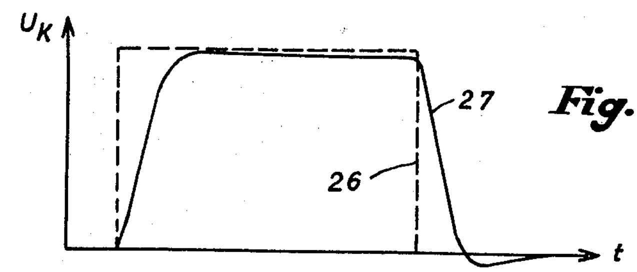

Fig. 3

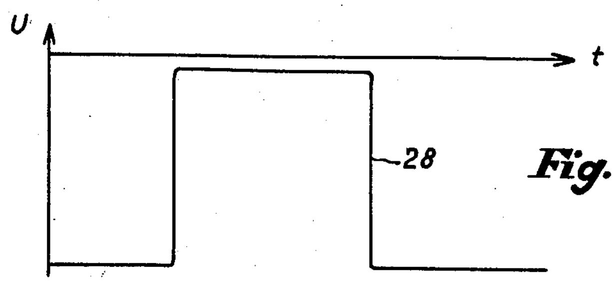

Fig. 4

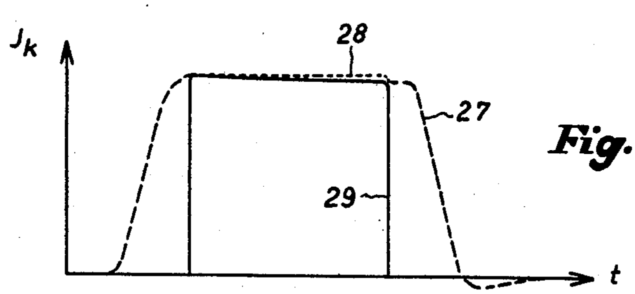

Fig. 5

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METHOD AND MEANS FOR CONTROL OF A PULSED BEAM OF CHARGE CARRIERS

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1 Claim. (Cl. 315—30)

This invention relates to charge carrier beam generators and, more particularly, relates to an improved method and apparatus for controlling the beam current of said generator whereby the acceleration potential is controlled intermittently.

It has been customary to utilize a direct acceleration potential in devices for the generation of an intermittently controlled beam of charge particles. In such devices, it is customary to bias the control electrode of the beam generating system with rectangular pulses to control the operation of the electron beam and to generate an intermittently pulsed beam. It is, however, desirable to utilize an alternating or intermittent acceleration potential instead of a direct voltage since the associated acceleration voltage generator is much simpler than the direct voltage generator and the insulation requirements are not as stringent.

Merely applying an alternating acceleration voltage to the electrodes of the beam generator (which may be biased in conventional fashion) will not achieve the desired results since, once the beam is "on," the acceleration voltage must thereafter remain fairly constant through the "on" period to prevent an adverse effect on the focussing of the electron beam. In theory, a square wave could be used as an acceleration voltage. However, in practice, the distortion of the leading and trailing edges of the square wave will be sufficient to upset the focussing of the beam.

It is, therefore, the primary object of this invention to provide an improved method and means for control of the acceleration and control electrode potentials of an electron beam generating system to provide beam pulses accelerated through a constant potential.

In accordance with this object, there is provided, in a preferred embodiment of this invention, means for applying a pulsated acceleration potential to the beam generating system. The acceleration potential may conveniently be a plurality of rectangularly-shaped pulses. The application of rectangular pulses to the beam generating system through a transformer having a low frequency band pass will distort the leading and trailing edges of the pulse but will rather faithfully reproduce the crest of the pulse.

During the application of the crest of the acceleration potential to the electron beam system, a control pulse which is preferably derived from the acceleration potential pulse, is applied to the control electrode of the electron beam generator to overcome the blocking bias thereon and release a beam. By maintaining the control pulses narrow with respect to the acceleration potential pulses and by triggering the control pulses at a predetermined time with respect to the acceleration pulses, the generated beam pulses can be carefully controlled. Each pulse is properly focussed since the applied acceleration potential does not vary during the pulse period.

In this manner, a pulse beam can be obtained in which each beam impulse is focussed properly throughout the entire pulse width.

The acceleration pulses may be generated and applied to the generator system through a pulse transformer which can be designed with a relatively low frequency band pass. The pulse crests are then transformed with

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relatively good fidelity even though the leading and trailing edges are somewhat distorted. Since the grid control pulses operate only during the central portion of the acceleration pulse, the distortion of the leading and trailing edges will not result in concomitant distortion of the beam pulses. In fact, in some applications, it is feasible to use a sinusoidally varying acceleration potential by dimensioning the control pulses so that the beam is produced only during the relatively flat peak of the sinusoidal wave.

This invention will be more easily understood by reference to the following description taken in conjunction with the accompanying drawings, of which:

FIG. 1 is a schematic diagram of a beam generating system in accordance with this invention;

FIG. 2 is a schematic diagram of a beam generating system in accordance with another embodiment of this invention;

FIG. 3 is a plot of the acceleration waveforms in which amplitude is plotted along the axis of abscissa as a function of time plotted along the axis of ordinates;

FIG. 4 is a plot of control pulse waveforms in which amplitude is plotted along the axis of abscissa as a function of time plotted along the axis of ordinates; and

FIG. 5 is a plot of beam amplitude in which amplitude is plotted along the axis of abscissa as a function of time plotted along the axis of ordinates.

In FIG. 1 there is shown an electron beam generator **1** comprising a cathode **2**, a control electrode **3** and a grounded anode **4**. Heating current is supplied to the cathode from source **5** which is energized by the transformer **6**.

The acceleration potential consisting of a series of rectangular waves is generated in generator **7**. The acceleration pulses are applied to cathode **2** to periodically pulse the cathode negative with respect to the grounded anode **4**. The control grid **3** is biased with respect to the cathode **2** by unidirectional biasing source **8** which is supplied with electrical energy through an isolating transformer **9**, the primary of which is at ground potential, the secondary of which is at the potential of the bias on the electron beam generating elements. To provide means to superimpose a control potential upon the D.C. bias of biasing source **8**, there is provided pulse generator **10** serially coupled with bias source **8** between the cathode **2** and control electrode **3** of generator **1**. The pulse generator is at the bias voltage level and supplied with energy through isolating transformer **11**, the primary of which is at the ground potential.

In order to supply control pulses from the pulse generator **10** which are synchronized with respect to the acceleration pulses from source **7**, there is provided a delay line **12** which couples the acceleration potential pulses from generator **7** and applies them to the pulse generator **10** through capacitor **13**. Thus, the generator **10** is locked to the operating frequency of the generator **7** and generates control pulses at a predetermined time subsequent to the generation of the control pulse generated by generator **7**. These control pulses have a shorter pulse width than the acceleration field pulses so that the electron beam is controlled by the width of the control pulse only.

In operation, the cathode **2** is biased positively with respect to the control electrode **3** as, for example, by application of a positive 120-volt bias. Thus, the beam generating system is so biased as to prevent the emission of an electron beam therefrom. When generator **7** is brought into operation, a pulse train will be applied to both the cathode and the control electrode. Despite the swing in potential of the two electrodes to follow the applied acceleration potential, the relative bias between the electrodes will be maintained to prevent beam emission.

Thus, for example, during the pulses applied by generator 7, the cathode would reach a voltage of −99.88 kv. while the control electrode would reach a potential of −100 kv. Despite the large acceleration potentials, it will be noted that the same relative bias between cathode and control electrode is maintained thereby precluding the generation of electron beams.

However, operation of the control pulse generator 10 would deliver a train of control pulses to overcome the cathode-grid bias thereby to initiate the discharge of an electron beam. The control pulse is delayed with respect to the application of the acceleration pulse by means of the delay element 12 and is dimensioned to have such a short pulse width as to terminate prior to the termination of the acceleration pulse. Thus, the control pulse will control the beam generator system and the sharpness of the leading and trailing edges of the control pulse controls the sharpness of the electron beam pulse.

It will be noted that all elements shown in FIG. 1 above the dotted line 14 are at high operating potentials.

In many applications it is desirable to avoid the use of operating components which are floating at the operating potentials. For example, the bias source 8 and generator 10 are at the operating potentials of the generator 1. In such applications the embodiment shown in FIG. 2 may advantageously be employed.

In FIG. 2 there is shown a high voltage pulse transformer 15 with bifilar secondary windings which is utilized to transmit both the acceleration pulse train and the control pulse train to the electron beam generator 1 having the same operating electrodes and the same identifying numerals as shown in FIG. 1.

A pulse generator 17 is provided and is coupled to the primary winding 16 of transformer 15 having bifilar secondary windings 18 and 19. Thus, the secondary voltage generated in the secondary windings 18 and 19 are at the same cyclic rate and phase. One terminal of the secondary winding 19 is grounded. A direct voltage generator 20 is serially coupled with a pulse generator 21 between one terminal of winding 18 and ground. The other terminal of the secondary windings 18 and 19 are respectively coupled to the cathode 2 and control electrode 3 of beam generator 1.

Thus, the bias established by source 20 is maintained between the cathode and the control grid 3 even though both elements are varying in potential according to the pulse train applied thereto from generator 17 through transformer 15. This bias is established at a level to keep the beam blocked.

The control impulse generator 21, however, will apply a pulse train which will overcome the cathode-grid bias during its negative excursions. The control pulses are keyed to the frequency of the pulse generator 17 but are delayed in phase with respect thereto by delay line 22. The control pulses are applied to the control elements of generator 1 through the secondary winding.

The magnetic fields of both bifilar coils 18 and 19 are fully compensated so that they have no significant effect on the core of transformer 15. Therefore, the inductance of the coil is negligible and the control pulses pass through the secondary windings without inductive distortion of the leading and trailing edges of the pulses. Thus, the beam control may be precisely and positively controlled.

The effect of the remaining inductance in the secondary windings 18 and 19 is reduced by resistor 23 coupled between the windings. This resistive coupling terminates the windings critically so that the windings act as delay elements. Secondary winding 18 is damped by resistor 24 and secondary winding 19 is damped by resistor 25.

The operation of the circuit shown in FIG. 3 may be more easily understood by simultaneous reference to FIGS. 3–5. In FIG. 3 there is shown the acceleration pulse 26 generated in the generator 17. However, the

passage of this pulse through transformer 15 will introduce distortion into the leading and trailing edges of the pulse as shown by waveform 27 of FIG. 3. However, since the transformer 15 has a low frequency band pass, the crest of the pulse is faithfully reproduced and there is little deviation between the crest of the transformed pulse and that of the generated pulse. In FIG. 4 there is shown a typical waveform of the control pulse 28 plotted to the same time scale as is FIG. 3. As will be noted, the leading edge of the control pulse is delayed with respect to that of the acceleration pulse and the width of the control pulse is short with respect to the width of the acceleration pulse so that its trailing edge occurs proir to the trailing edge of the acceleration pulse.

In FIG. 5 there is shown a plot of the electron beam plotted to the same time scale as FIGS. 3 and 4. As will be noted, the beam current pulse 29 has a sharp leading and trailing edge since these are determined by the control pulse 28 of FIG. 4 and not by the acceleration pulses represented by dotted line 27, FIG. 5. The crest is relatively flat, following the waveform of the acceleration pulse 27.

It will be noted that the amplitude of the beam current pulse 29 can be controlled by selection of the bias applied by generator 20. Thus, there is provided a simple and efficient system for the control of a pulsated electron beam generator system, which systems are advantageously employed for material treatment, such as boring, drilling, soldering, welding or heat treatment of such materials. This type of system may also be employed for electron microscopes when it is necessary to reduce object exposure or when it is desired to photograph the object with flash attachments.

This invention may be variously embodied and modified within the scope of the subjoined claim.

What is claimed is:

Apparatus for pulse control of the beam of an electron beam generator having an anode, a cathode, and control electrodes, and comprising a bias source for biasing said cathode positively with respect to said control electrode with an amplitude sufficiently high to cut off said electron beam, an acceleration pulse generator to generate a pulse train, consisting of a plurality of rectangular acceleration pulses, means coupling said acceleration pulse generator to said electron beam generator to pulse said anode positively with respect to said cathode and control electrode during each acceleration pulse of said train, a control pulse generator to provide a control pulse train consisting of rectangular control pulses, each control pulse of which is shorter than each acceleration pulse, means for applying said control pulses to said cathode and control electrode of said beam generator to overcome said bias, and a delay line coupling said acceleration pulse generator to said control pulse generator to key said control pulse generator so that each of said control pulses is generated during an acceleration pulse at a predetermined time subsequent to the generation of an acceleration pulse and so that said control pulses are at the same pulse repetition rate as said acceleration pulses.

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