

Sept. 10, 1946.

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2,407,297

ELECTRON DISCHARGE APPARATUS

Filed Oct. 11, 1941

3 Sheets-Sheet 1

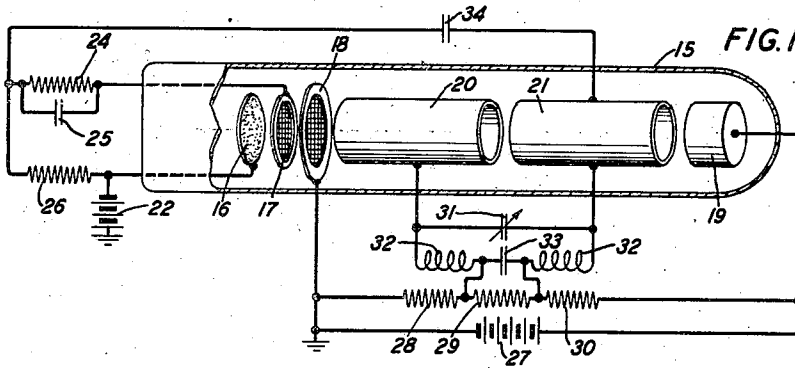
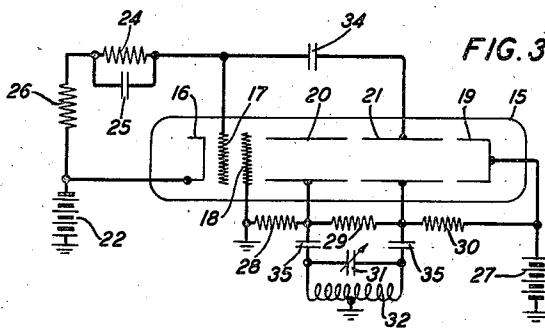
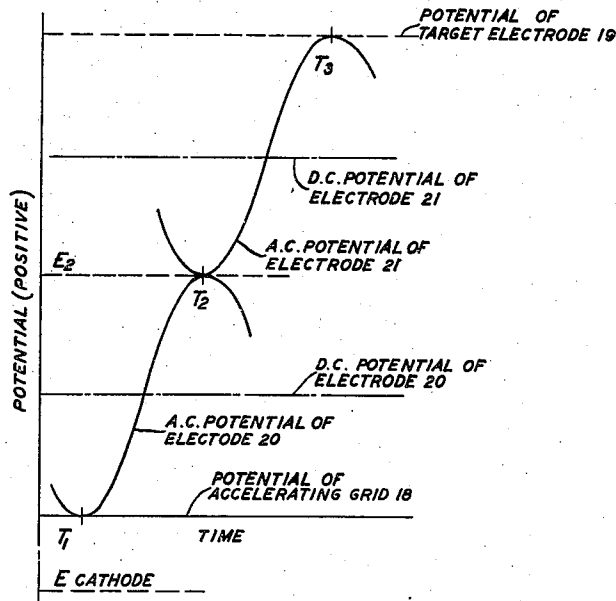


FIG. 2



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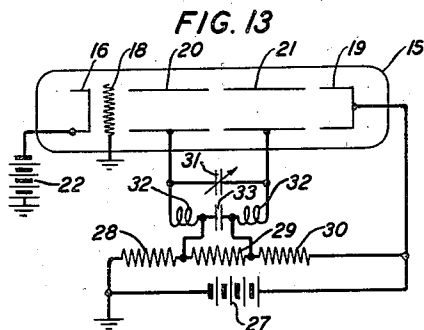
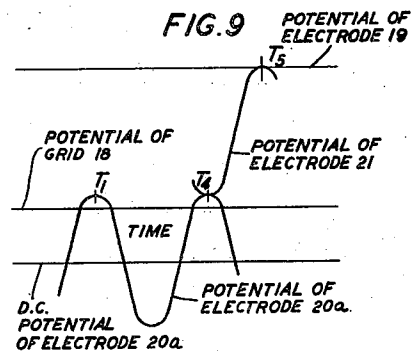
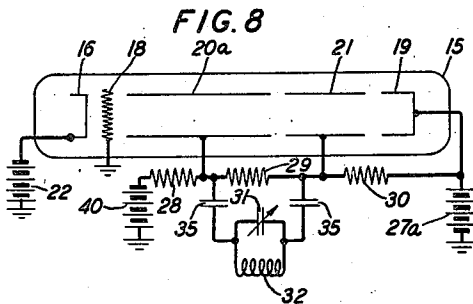
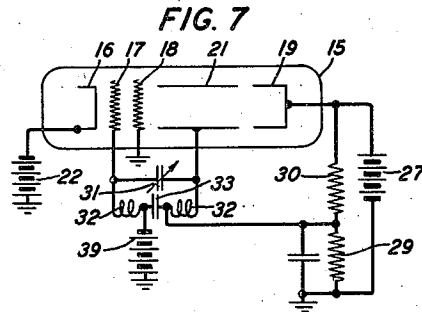
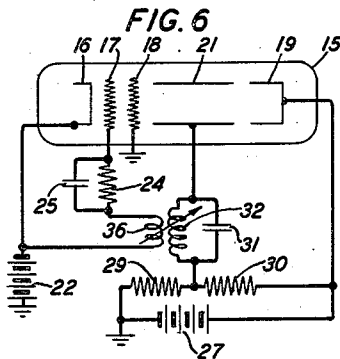
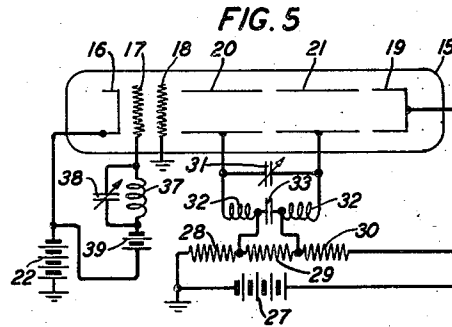
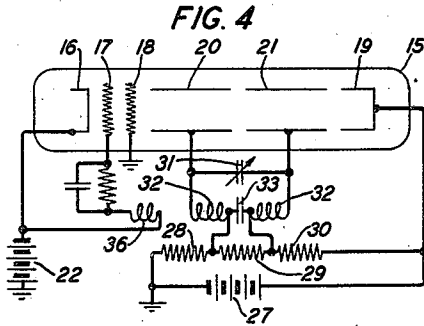
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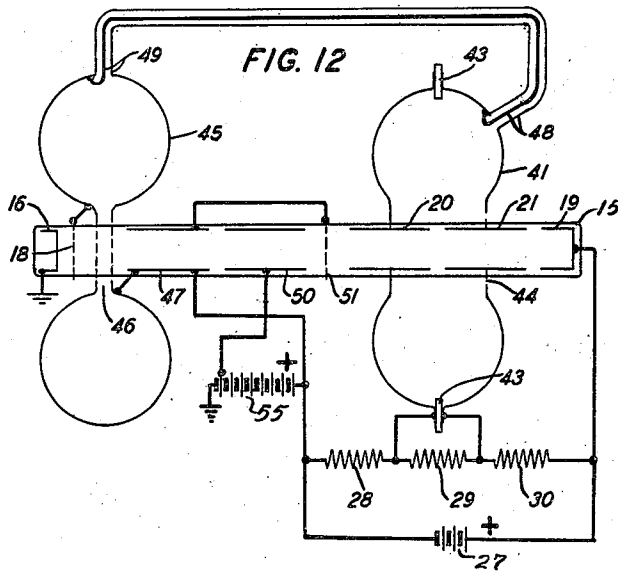
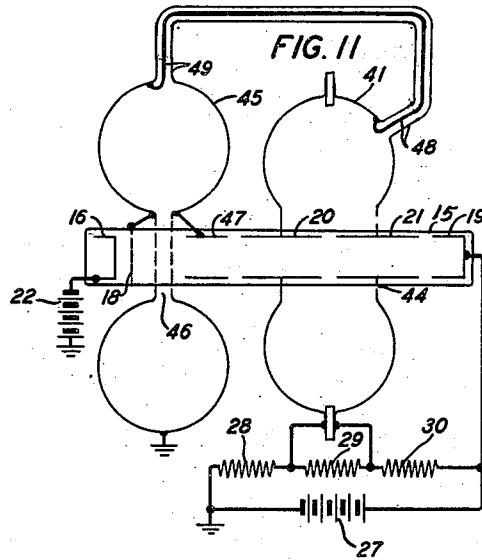
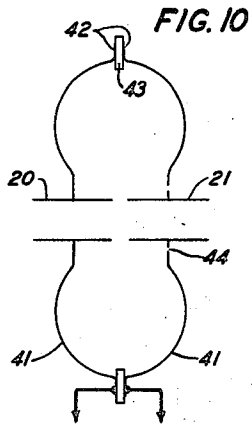
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ELECTRON DISCHARGE APPARATUS

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3 Sheets-Sheet 3



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UNITED STATES PATENT OFFICE

2,407,297

ELECTRON DISCHARGE APPARATUS

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Application October 11, 1941, Serial No. 414,630

18 Claims. (Cl. 250—36)

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This invention relates to electron discharge apparatus and more particularly to oscillation generators including electron discharge devices of the beam type.

One general object of this invention is to enable the generation, electronically, of high frequency oscillations. More specifically, objects of this invention are to:

Attain a high operating efficiency for electronic oscillation generators;

Enable the generation of oscillations over a wide band of frequencies including frequencies corresponding to wave-lengths in the centimeter range;

Simplify the construction of electronic oscillation generators; and

Enable the generation of high power oscillations.

In accordance with one feature of this invention, an electron stream is controlled to produce a periodic bunching or grouping of the constituent electrons thereof, the electron bunches or groups are accelerated and are then projected at constant average velocity through a time gradient of alternating potential and along a path adjacent which one or more oscillating electrodes are mounted, in such manner that the direct current potential energy of the electrons is converted into high frequency energy.

In one specific embodiment of this invention, the accelerated electron stream is projected toward a positive target electrode through a pair of coaxial cylindrical electrodes mounted in end-to-end relation and between which the oscillatory circuit is connected, the coaxial and target electrodes being maintained at successively higher positive potentials with respect to the source of the stream, and the cylindrical electrodes are made of such length relative to the operating frequency and the accelerating potential effective upon the electrons that the electrons deliver energy to the coaxial electrodes alternately and that at the time the electrons cross the gap between the coaxial electrodes these electrodes are at substantially the same instantaneous potential.

The invention and the above-noted and other features thereof will be understood more clearly and fully from the following detailed description with reference to the accompanying drawings in which:

Fig. 1 is a view, partly schematic, of an electronic oscillation generator illustrative of one embodiment of this invention;

Fig. 2 is a diagram showing the time-potential

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relation for the cylindrical oscillating electrodes in the electron discharge device illustrated in Fig. 1;

Figs. 3, 4 and 5 are circuit diagrams illustrating several modifications of the oscillation generator shown in Fig. 1;

Figs. 6 and 7 show electronic oscillation generators illustrative of another embodiment of this invention and wherein the discharge device comprises a single oscillating cylindrical electrode;

Fig. 8 illustrates another embodiment of this invention wherein the first cylindrical electrode is effective to produce a bunching of the electrons in the stream passing therethrough;

Fig. 9 is a diagram showing the time-potential relation for the cylindrical electrodes in the oscillation generator shown in Fig. 8;

Fig. 10 is a detail view in section illustrating a form of oscillatory circuit particularly suitable for use in oscillation generators constructed in accordance with this invention and operable at extremely high frequencies, for example frequencies corresponding to wave-lengths in the centimeter range; and

Figs. 11, 12 and 13 illustrate other embodiments of this invention wherein velocity variation is utilized to effect the bunching of the electrons in the stream.

Referring now to the drawings, the oscillation generator illustrated in Fig. 1 comprises an electron discharge device including an evacuated enclosing vessel 15 housing a cathode 16, which may be of the equipotential indirectly heated type and circular as shown, a control electrode or grid 17 and an accelerating electrode or grid 18 parallel to and coaxial with the cathode 16, a cup-shaped collector or target electrode 19, and a pair of cylindrical electrodes 20 and 21 mounted in end-to-end relation and coaxial with the cathode 16.

The accelerating electrode 18 is maintained at radio frequency ground potential and at a positive direct current potential with respect to the cathode 16 by a suitable source, such as a battery 22. The control grid 17 is connected to the cathode 16 through the grid leak resistor 24, shunted by the condenser 25, and the input resistor 26; the control grid is thus biased by the grid leak-condenser method. The cylindrical electrodes 20 and 21 and the collector or target electrode 19 are maintained at successively higher direct current potentials with respect to the accelerating grid 18 by a suitable source, such as a battery 27, connected across the resistors 28, 29 and 30. In a particular embodiment, the re-

sistances 28 and 30 may be equal and half as large as the resistance 29.

Connected between the cylindrical electrodes 20 and 21 is an oscillatory circuit comprising a condenser 31, which may be variable as shown, and a pair of equal inductances 32 connected to opposite plates of a blocking condenser 33 which is of large capacity relative to the condenser 31 to allow maintenance of the cylindrical electrodes 20 and 21 at different direct current potentials. The cylindrical electrode 21 is connected to the control grid 17 by way of a condenser 34 so that the alternating current potentials of the two are in phase, the connection by way of the condenser 34 providing feedback of some of the oscillating energy from the oscillatory circuit to the control grid.

For reasons which will appear hereinafter, the cylindrical electrodes 20 and 21 are made of the same length, given by the relation

$$L = \frac{2.96 \times 10^7 \sqrt{v}}{f} \quad (1)$$

where f is the oscillating frequency desired in cycles per second, v is the potential of the accelerating grid 18 relative to the cathode 16 in volts, and L is the length of each of the cylindrical electrodes in centimeters.

The device will be set into oscillation upon application of the direct current potentials to the electrodes thereof. The mode of operation will be understood from the following considerations with particular reference to the time-potential relation illustrated in Fig. 2. When the device is oscillating, because of the connection by way of the condenser 34, the alternating potential of the control grid 17 varies in phase with that of the cylindrical electrode 21. The alternating potential of the cylindrical electrode 20 is 180 degrees out of phase with that of the control grid 17 and the electrode 21. The accelerating grid 18, as noted heretofore, is at alternating current ground potential.

Because of the positive potentials upon the electrodes 19, 20 and 21, the electrons flowing by the accelerating grid 18 will have potential energy equal to Ve , where V is the potential of the battery 27 and e is the electron charge. Inasmuch as, as noted heretofore, the control grid 17 modulates the electron stream, the electrons emanating from the cathode 16 will flow by the accelerating grid 18 more or less in bunches or groups and the maximum electron current will flow when the control grid 17 is at its highest potential. At this time, indicated at T_1 in Fig. 2, the cylindrical electrode 20 is at its lowest potential and at the same potential as the accelerating grid 18. Hence the electrons enter the cylindrical electrode 20 with no appreciable change in their velocity.

The electrons projected into the electrode 20 traverse this electrode while its potential, and theirs, is increasing gradually, as indicated in Fig. 2, and at the time T_2 reach the gap between the electrodes 20 and 21. In thus traversing the electrode 20, the electrons, because of their inductive coupling to the electrode 20, deliver a portion of their energy to the electrode 20 and hence, to the oscillatory circuit 31, 32. The electron transit time of the electrons through the electrode 20 is equal to a half cycle of the oscillatory frequency.

At the time T_2 , as indicated in Fig. 2, the electrode 20 is at its maximum instantaneous potential and the electrode 21 is at its minimum instantaneous potential, the two potentials being

equal. Consequently, the electrons in crossing the gap between the electrodes 20 and 21 suffer no appreciable change in velocity. The electrons then traverse the electrode 21 while its potential is increasing and deliver some of their energy to the electrode 21 and thus to the oscillating circuit. In traversing the electrode 21, the electrons have their potential increased to a value, at time T_3 , equal to that of the target or collector electrode 19 and, hence, subsequently flow to the target or collector electrode with no appreciable change in velocity. This action is repeated by each group of electrons so that energy is delivered alternately to the two electrodes 20 and 21 whereby oscillations are generated in the circuit 31, 32.

It will be noted that the electrons in the device move through a time gradient of potential

$$\frac{\delta\phi}{\delta t}$$

so that they do not experience any acceleration nor any change in their kinetic energy. Hence, in the production of oscillations, the direct current potential energy of the electrons is converted or transformed into oscillating energy at the electrodes 20 and 21. It will be noted also that because of the phase relationships noted above, when the potential of the electrode 21 is increasing that of the electrode 20 is decreasing and when the potential of the former electrode reaches its maximum value, at time T_3 , the potential of the latter electrode is at its lowest value at a time one cycle later than the time T_1 , and at which, due to the in-phase variation in potentials of the electrode 21 and grid 17, the next group of electrons enters the cylindrical electrode 20. It will be noted further from Fig. 2 that the direct current potentials on the electrodes 20 and 21 are of such magnitude that the direct current potential difference between them is substantially equal to twice the maximum value of the alternating potential appearing on the electrodes 20 and 21. The direct current potential difference between the accelerating grid 18 and the electrode 20 and between the electrodes 21 and 19 is substantially equal to the maximum amplitude of the alternating potential appearing on the electrodes 20 and 21.

The generation of oscillations by conversion of the direct current potential energy into high frequency has been found to be highly efficient. It will be apparent, furthermore, from Equation 1 that the invention enables generation of oscillations throughout a wide range of frequencies and at exceedingly high frequencies, by correlation of the accelerating potential v and the length L of the cylindrical electrodes. Also, it will be appreciated that this invention enables the efficient generation of oscillations with an electron discharge device of simple construction and enables the production of oscillations of high power.

In some cases a magnetic field along and parallel to the axis of the enclosing vessel 15 may be utilized to concentrate the electron stream. Alternatively, an electron gun designed to produce and project a highly concentrated electron stream may be employed in place of the cathode, control grid and accelerating grid construction illustrated in Fig. 1.

In the modification, illustrated in Fig. 3, of the embodiment of this invention shown in Fig. 1 and described hereinabove, the several resistances 28, 29 and 30 for producing the requisite potential differences between the positive electrodes are

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connected directly between these electrodes and blocking condensers 35 are connected between the oscillatory circuit and the electrodes 20 and 21, which circuit is grounded at the mid-point of the inductance 32. Hence, the blocking condenser, such as the condenser 33 in Fig. 1, is eliminated from the oscillatory circuit.

In another modification, illustrated in Fig. 4, of the embodiment of this invention shown in Fig. 1, the condenser 34 is omitted and energy is fed back inductively from the oscillatory circuit 31, 32 by way of a coil 35 inductively coupled to this circuit.

In a further modification illustrated in Fig. 5, a tunable circuit 37, 38, inductively related to the oscillatory circuit 31, 32 is connected to the control grid 17 and the requisite negative bias for this grid is provided by a battery 39. It will be understood, of course, that such a battery may be utilized also in place of the grid leaks shown in Figs. 1, 3 and 4.

Although in the oscillation generators illustrated in Figs. 1, 3, 4 and 5 a pair of oscillating electrodes 20 and 21 has been shown, a number of pairs of such electrodes may be employed, one group of alternate electrodes being connected to one side of the oscillatory circuit and the remainder to the other side, the various electrodes being biased at successively higher positive potentials toward the collector electrode 19 and of such relative magnitudes that when the electrons cross the gap between adjacent electrodes such adjacent electrodes are at substantially the same instantaneous potential.

In the oscillation generators illustrated in Figs. 6 and 7, a single cylindrical electrode is employed and the oscillatory circuit is coupled to the control grid 17 either inductively, as shown in Fig. 6, or directly, as shown in Fig. 7. As in the generators described hereinabove, the control grid 17 is biased negative and the accelerating grid 18 is maintained at radio frequency ground potential and at a positive direct current potential relative to the cathode. The electron groups emanating from the cathode are accelerated by the positive grid 18 and projected into the cylindrical electrode 21 at a time when the instantaneous potential of the electrode 21 is at its minimum value, equal to that of the accelerating grid, and rising, so that the electrons suffer no substantial change in their velocity or kinetic energy. In traversing the cylindrical electrode 21, the electrons deliver energy thereto by virtue of the inductive action of the stream upon the electrode 21, whereby the direct current potential energy of the electrons is converted into high frequency energy. After leaving the electrode 21, the electrons flow to the target or collector electrode 19 with no appreciable change in velocity.

In the oscillators described thus far the bunching or grouping of the electrons is obtained by the use of the negatively biased control grid 17. This may be effected also in other ways, one of which is illustrated in Fig. 8. As illustrated in the latter figure, the control grid is omitted and the cylindrical electrode 20a is twice as long as the cylinder 21, for reasons which will be apparent from the description hereinafter, the cylindrical electrode 21 being of the length given by Equation 1. The oscillating circuit 31, 32 is connected between the cylindrical electrodes 20a and 21 through the blocking condensers 35 and the electrodes 21 and 19 are maintained at successively higher positive potentials by the battery 27a. The accelerating electrode 18 is at radio

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frequency ground potential and is maintained at a positive direct current potential with respect to the cathode 16 by the battery 22. The cylindrical electrode 20a is biased negatively with respect to the accelerating grid 18 by the battery 40 and at such a value that the maximum instantaneous potential of the cylindrical electrode 20a during oscillation of the device is substantially equal to the potential of the accelerating grid, as indicated in Fig. 9. The direct current potential of the cylindrical electrode 21 is such that, as indicated in Fig. 9, the minimum instantaneous potential of the electrode is substantially equal to the maximum instantaneous potential of the electrode 20a so that electrons crossing the gap between the electrodes 20a and 21 suffer no increase in velocity.

When the device is oscillating, electrons enter the cylindrical electrode 20a when the potential of the latter is at its maximum value at a time, indicated at T_1 in Fig. 9, and traverse this electrode in one cycle during which the potential of the electrode 20a first decreases to its minimum value and then increases to its maximum value, so that no conversion of the potential energy of the electrons occurs. The electrons are projected into the electrode 21 at the time T_4 and then traverse this electrode until time T_5 , while its potential is rising whereby the electrons deliver energy to the electrode 21. It will be noted that because of the magnitude of the direct current potential upon the electrode 20a and the length of this electrode, electrons will be projected through the electrode in groups or bunches so that groups or bunches of electrons are projected periodically and in the proper phase relation into the electrode 21. When the instantaneous potential of the electrode 20a is appreciably negative with respect to the accelerating grid 18, projection of electrons into the electrode 20a is prevented. As in the other embodiments of this invention described hereinabove, in the oscillator shown in Fig. 8 the electrons traverse the cylindrical electrodes with substantially no change in velocity or kinetic energy and oscillations are produced by conversion of the direct current potential energy of the electrons into high frequency energy.

In oscillation generators operable at extremely high frequencies, the oscillating circuit preferably is in the form of a cavity resonator. A suitable construction for such a resonator is illustrated in Fig. 10 and comprises a pair of complementary semitoroidal halves 41 having annular peripheral flanges 42 between which a dielectric member 43 is disposed, the two halves being joined at their inner edges to the electrodes 20 and 21. In order to maintain the alternating current potentials at the opposite ends of each of the electrodes 20 and 21 substantially equal, the halves of the cavity resonator may be provided with apertures 44 to allow some leakage of the alternating current field from within the resonator. This is particularly desirable in cases where the electrodes 20 and 21 are of fairly large length relative to their diameter in which, because of the wave guide character of these electrodes, the alternating current potential between the juxtaposed ends of the two electrodes may be considerably higher than that between the outer ends of these electrodes.

The bunching or grouping of the electrons projected into the cylindrical electrode 20 may be effected also by velocity variation of the electrons emanating from the cathode 16, in conjunction

with a drift space between the gap at which the velocity variation is produced and the inlet end of the electrode 20. Two illustrative constructions are shown in Figs. 11 and 12. In Fig. 11, a toroidal cavity resonator 45 is provided with juxtaposed central reticulated portions defining a velocity variation gap 46 across which the electrons emanating from the cathode 16 are projected. Connected to the resonator 45 are the accelerating grid 18 and a cylindrical electrode 47 which is coaxial with the electrodes 20 and 21 and defines a drift space through which the electrons are projected. The drift space electrode 47 is made half as long as the electrodes 20 and 21 so that the electrons are bunched or grouped at the gap between the electrodes 47 and 20 and the bunches are substantially one cycle apart in time relation. The oscillating circuit, which is of the construction shown in Fig. 10, is connected between the electrodes 20 and 21 and energy is fed back from the circuit to the resonator 45 by way of coaxial lines 48 and 49.

In the construction illustrated in Fig. 12, an additional cylindrical electrode 50, coaxial with the electrodes 47, 20 and 21, and an additional grid 51, connected directly to the electrode 47 are provided. During operation of the device, the electrode 47 is operated at a high direct current potential and the electrode 50 is operated at a low direct current potential as by a battery 55. For example, the electrode 47 may be operated at of the order of 1000 volts positive and the electrode 50 at of the order of 50 volts positive. The electrons emanating from the cathode 16 are velocity varied at the gap 46, projected at high potential through the electrode 47, slowed down, from 1000 volts to 50 volts in the specific example given, and then speeded up, from 50 to 1000 volts in the specific example given, and projected into the electrode 20. This action upon the electrons produces a very highly concentrated bunching thereof, which bunching is maintained during the flow of the electrons through the electrodes 20 and 21 and to the target or collector electrode 19. The potential energy of the electrons is converted at the electrodes 20 and 21 in the manner described hereinabove whereby oscillations are generated.

In the oscillation generator shown in Fig. 13, which is generally similar to that shown in Fig. 1 except that the control grid 17 is omitted, the electron stream is velocity varied at the gap between the accelerating grid 18 and the cylindrical electrode 20 in such manner that most of the electrons pass through the electrode 21 during the half cycle in which the potential of the electrode 21 is increasing so that the electrons give up energy to this electrode. The electrons are, in effect, segregated in time so that most of them are phased correctly to deliver energy to the electrode 21.

Although several specific embodiments of this invention have been shown and described, it will be understood that they are but illustrative and that various modifications may be made therein without departing from the scope and spirit of this invention as defined in the appended claims.

What is claimed is:

1. An electronic oscillation generator comprising a target electrode, means including a source and control means in cooperative relation therewith for projecting periodically groups of electrons toward said target electrode, means maintaining said target electrode at a positive potential relative to said source, and means for converting the direct current potential energy of

said electrons into high frequency energy, said last means including an output electrode intermediate said source and said target electrode and adjacent the electron path to said target electrode, means biasing said output electrode at a positive potential lower than the potential of said target electrode relative to said source, an oscillatory circuit coupled to said output electrode, and feedback means coupling said circuit and said control means.

2. An electronic oscillation generator comprising a target electrode, means including a source for projecting an electron stream toward said target electrode, means maintaining said target electrode at a positive potential relative to said source, and means for producing a grouping of the electrons in said stream and increasing the potential of said electrons at a region intermediate said source and said target electrode, without substantially altering the velocity of said electrons in said region, said last means including an output electrode at said region in inductive relation to said electron stream, means biasing said output electrode at a positive potential lower than the potential of said target electrode relative to said source, a control means adjacent said source, and an oscillatory circuit connected to said output electrode and coupled in feedback relation to said control means.

3. The method of generating electrical oscillations which comprises producing a stream of electrons, accelerating the electron stream, successively increasing the potential of the electrons in said stream in a pair of regions traversed thereby while maintaining the velocity of said electrons substantially constant, extracting energy from said stream alternately at said regions, and feeding back a portion of the energy thus extracted to said stream adjacent the region of acceleration thereof.

4. An electronic oscillation generator comprising a target electrode, means including a source for projecting a stream of electrons toward said target electrode, means for producing along the path traversed by said stream a direct current electric field increasing positively with distance away from said source and for producing also along said path a time gradient of electric potential, said last means comprising an output electrode adjacent said path, means biasing said output electrode and said target electrode at positive potentials with respect to said source and an oscillatory circuit connected to said output electrode, and means coupled to said oscillatory circuit for cyclically varying said stream adjacent said source.

5. An electronic oscillation generator comprising a cylindrical electrode, an oscillatory circuit connected to said cylindrical electrode, a target electrode opposite one end of said cylindrical electrode, means opposite the other end of said cylindrical electrode for projecting periodically groups of electrons into said cylindrical electrode and toward said target electrode, said means including a cathode, means for controlling the electrons emanating from said cathode and an accelerating grid, means maintaining said accelerating grid, cylindrical electrode and target electrode at successively higher positive potentials with respect to said cathode, and alternating current coupling means between said oscillatory circuit and said controlling means.

6. An electronic oscillation generator comprising a target electrode, means for projecting a stream of electrons toward said target electrode,

means for successively increasing the potential of the electrons in said stream at a pair of spaced regions along the path traversed by said stream, said means including a pair of electrodes at said regions and direct current potential means biasing said electrodes at different potentials positive with respect to said first means, the biasing potential of the one of said electrodes furthest along said path being greater than the biasing potential of the other of said electrodes, an oscillatory circuit connected between said electrodes, and control means for said stream coupled to said oscillatory circuit.

7. An electronic oscillation generator comprising a target electrode, means for projecting an electron stream toward said target electrode, and means for producing along the path traversed by said stream a direct current potential increasing with distance toward said target electrode and for producing along said path a time gradient of electric potential, said last means including a pair of coaxial hollow electrodes mounted in end-to-end relation along said path, direct current biasing means for said hollow and target electrodes and an oscillatory circuit connected between said hollow electrodes.

8. An electronic oscillation generator comprising means for producing an electron stream, means for cyclically varying the intensity of said stream, means for accelerating the varied stream, means for producing a direct current electric field along which the accelerated stream is projected and increasing positively in the direction of projection of said stream, said last means including a pair of cylindrical electrodes mounted in end-to-end relation and traversed by said stream, a target electrode for receiving said stream and means for impressing direct current potentials upon said cylindrical and target electrodes, an oscillatory circuit connected between said cylindrical electrodes, and means coupling said circuit to said stream varying means.

9. An electronic oscillation generator comprising a target electrode, means including an electron source for projecting an electron stream toward said target electrode, a first electrode between said source and said target electrode and adjacent the electron path between said source and said target electrode, a second electrode between said first electrode and said target electrode and adjacent said path, means maintaining said first, second and target electrodes at successively higher positive potentials with respect to said source, an oscillatory circuit connected between said first and second electrodes, and means for controlling said electron stream coupled to said oscillatory circuit.

10. An electronic oscillation generator comprising a cathode, a control electrode and an accelerating electrode in cooperative relation with said cathode, a target electrode, a pair of coaxial cylindrical electrodes mounted in end-to-end relation between said cathode and said target electrode, means biasing said control electrode negatively, means capacitively connecting said control electrode to the cylindrical electrode furthest removed from said cathode, means biasing said accelerating electrode, said cylindrical electrodes, and said target electrode at positive potentials with respect to said cathode successively higher in accordance with their positive relation to said cathode, and an oscillatory circuit connected between said cylindrical electrodes.

11. An electronic oscillation generator comprising a cylindrical electrode, a target electrode op-

posite one end of said cylindrical electrode, means opposite the other end of said cylindrical electrode for projecting an electron stream there-through and comprising a cathode, a control means and an accelerating electrode, an oscillatory circuit connected to said cylindrical electrode, a feedback coupling between said circuit and said control means, means maintaining said accelerating and target electrodes at positive direct current potentials with respect to said cathode, said cylindrical electrode being of the length given by the relation

$$L = \frac{2.96 \times 10^7 \sqrt{v}}{f}$$

where L is said length, v is the direct current potential of said accelerating electrode and f is the operating frequency, and means biasing said cylindrical electrode at a potential such that the minimum instantaneous potential thereof is substantially equal to the direct current potential of said accelerating electrode.

12. An electronic oscillation generator comprising a pair of coaxial cylindrical electrodes mounted in end-to-end relation, a target electrode opposite one end of one of said cylindrical electrodes, means opposite the other end of the other of said cylindrical electrodes for projecting an electron stream thereinto, said means including a cathode and an accelerating electrode, an oscillatory circuit connected between said cylindrical electrodes, and means applying positive direct current potentials to said accelerating, cylindrical and target electrodes such that the minimum instantaneous potential of said one cylindrical electrode is substantially equal to the maximum instantaneous potential of said other cylindrical electrode and the minimum instantaneous potential of said other cylindrical electrode is substantially equal to the direct current potential of said accelerating electrode.

13. An electronic oscillation generator in accordance with claim 12 wherein said cylindrical electrodes are each of the length given by the relation

$$L = \frac{2.96 \times 10^7 \sqrt{v}}{f}$$

where L is the length, v is the direct current potential of said accelerating electrode and f is the operating frequency.

14. An electronic oscillation generator in accordance with claim 12 wherein said other cylindrical electrode is of twice the length of said one cylindrical electrode and said one cylindrical electrode is of the length given by the relation.

$$L = \frac{2.96 \times 10^7 \sqrt{v}}{f}$$

where L is the length, v is the direct current potential of said accelerating electrode and f is the operating frequency.

15. An electronic oscillation generator comprising a cylindrical electrode, a target electrode opposite one end of said cylindrical electrode, means opposite the other end of said cylindrical electrode for projecting periodically groups of electrons thereinto, said means comprising a cathode and means for velocity varying the electrons emanating therefrom, an oscillatory circuit connected to said cylindrical electrode, means coupling said oscillatory circuit to said velocity varying means, and means biasing said cylindrical electrode at a positive potential with respect to said cathode and applying a higher positive direct current potential to said target electrode,

16. An electronic oscillation generator comprising a pair of coaxial cylindrical electrodes mounted in end-to-end relation, a target electrode opposite one end of one of said cylindrical electrodes, means opposite the other end of the other of said cylindrical electrodes for projecting periodically groups of electrons thereinto, said means comprising a cathode, means in cooperative relation therewith for velocity varying the electrons emanating therefrom and means defining a drift space into which the velocity varied electrons are projected, an oscillatory circuit connected between said cylindrical electrodes, means coupling said oscillatory circuit to said velocity varying means, and means applying positive potentials, successively higher, to said other cylindrical electrode, said one cylindrical electrode and said target electrode.

17. Electron discharge apparatus comprising a pair of coaxial cylindrical electrodes mounted in end-to-end relation, a target electrode opposite one end of one of said cylindrical electrodes, means opposite the other end of the other of said cylindrical electrodes for periodically projecting groups of electrons thereinto, said means comprising a cathode, a control means and an accelerating anode, a resonant circuit connected be-

tween said cylindrical electrodes, and means applying successively higher positive potentials relative to said accelerating electrode to said other cylindrical electrode, said one cylindrical electrode and said target electrode, such that the minimum instantaneous potential of said one cylindrical electrode is substantially equal to the maximum instantaneous potential of said other cylindrical electrode and the minimum instantaneous potential of said other cylindrical electrode is substantially equal to the direct current potential of said accelerating electrode, each of said cylindrical electrodes being of a length such that the electron transit time therethrough is substantially equal to one-half the periodicity of projection of said electron groups.

18. The method of generating electrical oscillations which comprises producing a stream of electrons, accelerating the electrons constituting said stream, projecting said electrons through an electric field, maintaining a substantially field-free space adjacent the path traversed by said electrons in flowing through said electric field, and extracting energy from said electrons at a region in said path without substantially altering the kinetic energy of said electrons.

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