March 22, 1938. R. A. HEISING 2,111,625

ELECTRON DISCHARGE DEVICE

Filed Oct. 3, 1935

FIG. 1

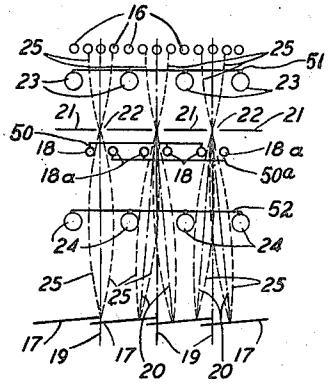


FIG. 2

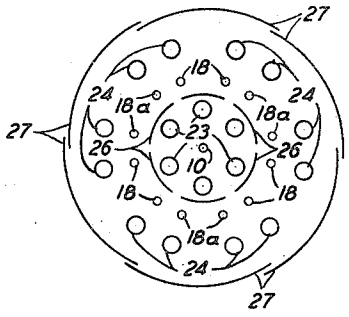


FIG. 3

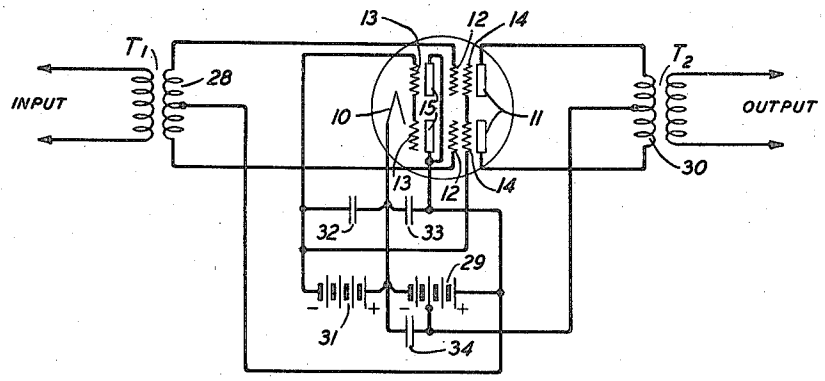
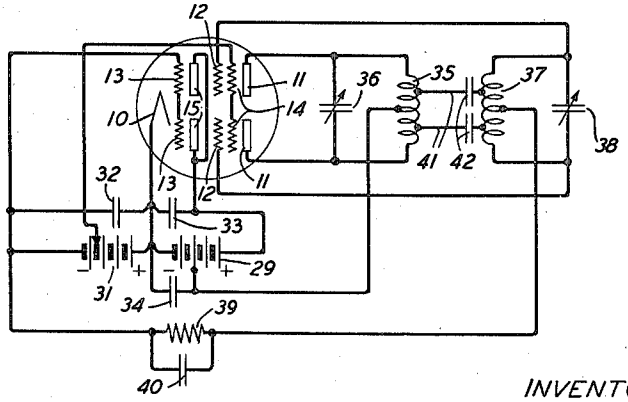


FIG. 4



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2,111,625

UNITED STATES PATENT OFFICE

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ELECTRON DISCHARGE DEVICE

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8 Claims. (Cl. 250—27.5)

This invention relates to electron discharge devices and more particularly to such devices capable of generating and amplifying ultra-high frequency impulses.

As is known in the art, in electron discharge devices including at least a cathode, an anode and a control electrode or grid, the electrons emanating from the cathode are subjected to the potential on the control electrode or grid in their passage to the anode. In present devices the electrons are under the influence of the grid potentials throughout a relatively large distance in the path the electrons traverse in passing to the anode. At ultra-high frequencies, the time required for the electrons to traverse the distance in which they are acted upon by the grid potentials may become too great a part of the cycle at which it is desired to operate the device. To overcome this, it has been proposed to make the electrode spacings extremely small. However, the attainment of such small spacings involves mechanical and electrical difficulties and, furthermore, may necessitate the use of relatively small electrodes so that the power output obtainable from devices so constructed is relatively small.

In electron discharge devices of conventional construction, at ultra-high frequencies the rapidly reversing grid potentials cause a large proportion of the electrons emanating from the cathode to execute a to and fro or oscillating motion between the grid and the cathode, which motion results in a power loss. Also, as a result of this motion, the passage of some of the electrons from the grid to the anode is not initiated until late in the cycle so that these electrons extract energy from the grid circuit which is not compensated for by movement of the electrons away from the grid and to the anode. The resulting loss of energy, which is commonly known as the active grid loss, becomes of appreciable magnitude at ultra-high frequencies.

One object of this invention is to amplify and to generate impulses of ultra-high frequencies.

Another object of this invention is to reduce the active grid losses in electron discharge devices whereby the efficiency of such devices, particularly at ultra-high frequencies, is increased.

A further object of this invention is to enable the use of relatively wide electrode spacings and relatively large electrodes in electron discharge devices adapted for the generation and amplification of ultra-high frequency impulses.

In one illustrative embodiment of this invention, an electron discharge device comprises an incandescible cathode, a plurality of anodes having juxtaposed end portions, and a plurality of control electrode elements disposed between the cathode and the anodes and adapted to influence electron beams from the cathode so that each of the beams impinges alternately upon two of the anodes.

In accordance with one feature of this invention an accelerating electrode is provided between the cathode and control electrode, the accelerating electrode having openings or slits in alignment with the juxtaposed end portions of two of the anodes and with the corresponding opening or space between two of the control electrode elements. This accelerating electrode preferably is operated at a positive potential greater than that of the anodes so that electrons passing in the region between the control electrode and anodes will be subjected to a retarding field and will have a low velocity when reaching the anodes, whereby a high operating efficiency is obtained.

In accordance with another feature of this invention an auxiliary electrode is provided between the cathode and the accelerating electrode for focussing electron beams upon the openings or slits in the accelerating electrode. In one form, this auxiliary electrode may comprise elements on opposite sides of normals extending from the cathode to the openings or slits, and these elements may have either a negative or positive potential relative to the cathode.

In accordance with a further feature of this invention another auxiliary electrode is provided for focussing the electron beams upon the anodes. This electrode may comprise a plurality of elements disposed between the control electrode elements and the anode and on opposite sides of lines extending from the openings or slits in the accelerating electrode to the juxtaposed end portions of the corresponding anodes.

The various electrodes may be arranged in parallel planes or may be arranged in coaxial cylindrical boundaries.

At ultra-high frequencies, a time delay may occur between the potential changes on the control electrode elements and the corresponding deflections of the electron beams at their points of focus upon the anodes. In accordance with still another feature of this invention the deleterious effects of such time delay are prevented by a shifting in phase of the variable potentials appearing upon the control electrode elements and upon the anodes. For example, either the input or output circuit of the device may be de-

tuned slightly to provide the proper phase shift. If the device is utilized as an oscillation generator, the input and output circuits may be connected by a transmission line or other delay circuit to provide the proper phase shift in the potentials upon the control electrode elements and the anodes. This feature is claimed in my application Serial No. 79,485, filed May 13, 1936, which is a division of the present application.

It will be apparent that in devices constructed in accordance with this invention the electrons flowing to the anodes are subjected to the influence of the control electrode throughout but a small portion of the path they traverse in passing to the anodes. The small change of direction of motion of the electrons produced in the vicinity of the control electrodes is multiplied because of the movement of the beams analogous to levers so that a large displacement of the electron beams occurs at their points of focus upon the anodes. Hence, the electrodes may be relatively widely spaced and the difficulties attendant upon the extremely small electrode spacings used heretofore in ultra-high frequency devices are obviated.

Furthermore, inasmuch as in devices constructed in accordance with this invention the electrons have a very high velocity as they come through the openings in the accelerating electrode, the electrons will be under the influence of the control grid for but a small portion of a cycle at the operating frequency. The movement of the electrons under the influence of the potentials upon the control grid will be small and a correspondingly small energy loss will obtain.

The invention and the several features thereof will be understood more clearly and fully from the following detailed description with reference to the accompanying drawing in which:

Fig. 1 is a diagrammatic view showing the form and arrangement of the electrodes in an electron discharge device illustrative of one embodiment of this invention;

Fig. 2 is a diagrammatic view illustrating another embodiment of this invention wherein the electrodes are arranged coaxially;

Fig. 3 shows a typical amplifier circuit including an electron discharge device constructed in accordance with this invention; and

Fig. 4 illustrates a typical oscillator circuit including an electron discharge device constructed in accordance with this invention and including also a time delay element for providing a phase shift between the potentials upon the control electrode elements and the anodes.

Referring now to Figs. 3 and 4 of the drawing, the electron discharge devices shown therein comprise, generally, a cathode 10, a plurality of anodes 11, and a control electrode 12 disposed between the cathode and the anodes. Disposed between the cathode 10 and the control electrode 12 is a focussing electrode 13. Another focussing electrode 14 is positioned between the control electrode 12 and the anodes 11. An auxiliary or accelerating electrode 15 is arranged between the focussing electrode 13 and the control electrode 12.

As shown in Fig. 1, the cathode 10 may comprise a plurality of filaments 16, which may be connected in series or in parallel, arranged in a plane. The anodes 11 may be flat plates 17 disposed at a very small angle to the cathode plane, with adjacent end portions overlapping. The control electrode 12 may include a plurality of pairs of linear metallic wires or rods 18 and 18a positioned parallel to the cathode plane and on opposite sides of normals 19 extending from the cathode plane to the overlapping end portions of the plates 17. The wires or rods 18 are electrically connected together, as by a conductor 50, and the wires or rods 18a are similarly connected together, as by a conductor 50a.

If the anodes 11 are operated at a positive potential, electrons will flow from the cathode 10 to the anodes 11 in substantially linear paths and some of the electrons will pass between the wires or rods 18 and 18a of the control electrode and be subject to potentials upon the control electrode. Thus, if the potentials upon the wires or rods 18 and 18a are varied, the electron beams passing therebetween will be deflected in accordance with such potential variations and may be caused to impinge alternately upon two of the anode plates 17 as indicated by the broken lines 20 in Fig. 1.

The accelerating electrode 15 may be composed of a plurality of flat plates 21 disposed parallel to the cathode plane and spaced to form openings or slits 22 in alignment with the normals 19. Alternatively, the accelerating electrode 15 may be a single flat plate having suitable openings or slits therein. Preferably the electrode 15 is operated at a greater positive potential, relative to the cathode 10, than the potential on the anodes 11 so that the electrons are subjected to a retarding force between the control electrode 12 and the anodes 11 and, therefore, will have a relatively low velocity when reaching the anodes, whereby a high operating efficiency is obtained.

The electrode 13 may include a plurality of pairs of metallic rods or wires 23 electrically connected together, as by a conductor 51, and positioned parallel to the cathode plane and on opposite sides of the normals 19. The rods or wires 23 may be operated at either a positive or negative potential, the potential preferably being such that the electron beams are focussed upon the openings or slits 22 in the accelerating electrode 15.

The electrode 14 similarly may be composed of a plurality of pairs of metallic rods or wires 24 electrically connected together, as by a conductor 52, and arranged parallel to the cathode plane and on opposite sides of the normals 19. Preferably the electrode 14 is operated at a negative potential of such magnitude that the electron beams are focussed upon the overlapping end portions of the anode plates 17.

As indicated by the dotted lines 25 in Fig. 1, electrons emanating from the cathode 10, under the influence of the positive potentials upon the anode plates 17 and the plates 21 of the accelerating electrode 15 travel toward the accelerating electrode 15. The electrons are subjected to the field of the elements 23 of the electrode 13 and are focussed thereby upon the openings or slits 22 and, because of their high velocities, pass through the openings or slits and between the elements 18 and 18a of the control electrode 12. If the elements 18 and 18a are at the same potential, the electrons tend to spread uniformly after passing the control electrode. This tendency to spread is counteracted by the field of the elements 24 of the electrode 14 and the electrons are concentrated to form beams each focussed upon the overlapping end portions of the anode plates 17. If an alternating potential is applied between the elements 18 and 18a each of the electron beams will be deflected in accordance with the potential variations and impinge alternately

upon two of the anode plates 17, as indicated by the dotted lines 20, the plates 17 being so connected that the electrons flowing thereto from the several beams are in phase. For example, if a device includes four anode plates 17, as shown in Fig. 1, alternate plates 17 may be electrically connected together, as by conductors 53.

As shown in Fig. 2, the invention may be embodied also in electron discharge devices having coaxially arranged electrodes. In this embodiment, the cathode 10 may be a single linear filament or a plurality of filaments arranged in a cylindrical boundary, and the focussing electrode 13 may comprise a plurality of metallic linear wires or rods 23 which are equally spaced, parallel to each other and to the cathode 10, and are arranged in a cylindrical boundary about and coaxial with the cathode. The accelerating electrode 15 may include a plurality of arcuate plates 26 arranged in a cylindrical boundary coaxial with the cathode 10. The control electrode elements 18 and 18a, which may be wires or rods disposed parallel to each other and to the cathode 10, are disposed in a cylindrical boundary coaxial with the cathode 10, the elements 18 being electrically connected together, as by a conductor 50, and the elements 18a being similarly connected together, as by a conductor 50a. Likewise, the elements 24 of the focussing electrode 14 may be linear wires or rods disposed parallel to each other and to the cathode 10 and arranged in a cylindrical boundary coaxial with the cathode 10. The anodes 11 may be arcuate plates 27 having overlapping end portions and forming a substantially cylindrical enclosure coaxial with the cathode 10, alternate plates 27 being electrically connected together, as by conductors 53. The several electrodes, it will be apparent, are arranged to provide unimpeded radial paths for electrons to the overlapping edges of the anodes.

The paths traversed by electrons in the device shown in Fig. 2 will be clear, it is believed, from the detailed description hereinabove with reference to Fig. 1.

A typical amplifier circuit incorporating an electron discharge device constructed in accordance with this invention is illustrated schematically in Fig. 3. As shown in this figure, the corresponding elements 18 and 18a of the control electrode 12 are connected to opposite ends of the secondary 28 of an input transformer T_1, the midpoint of the secondary 28 being connected to the positive terminal of a source, such as a battery 29. The anodes 11 are connected to opposite ends of the primary 30 of an output transformer T_2, the midpoint of the primary being connected to a suitable positive tap on the battery 29.

Another source, such as a battery 31 is provided for applying suitable negative potentials to the focussing electrodes 13 and 14. The accelerating electrode 15 may be connected to the positive terminal of the battery 29.

Appropriate condensers 32, 33 and 34 may be connected between the cathode 10 and the focussing electrode 13, accelerating electrode 15 and anodes 11 as shown.

In the typical oscillator circuit illustated in Fig. 4, the anodes 11 are connected to opposite ends of an inductance 35 which is shunted by a suitable variable condenser 36. Similarly, corresponding elements of the control electrode 12 are connected to opposite ends of an inductance 37, which is in parallel with a variable condenser 38. The midpoint of the inductance 37 is connected to the negative terminal of the source 31 through a resistance 39 shunted by a condenser 40.

At ultra-high frequencies, because of the electron transit times, a time delay may occur between the potential changes on the elements 18 and 18a of the control electrode 12 and the corresponding deflections of the electron beams at their points of focus upon the anodes 11. This time delay may be counteracted by slightly detuning either the control electrode or anode circuits by varying the condenser 38 or 36, respectively. The requisite shifting in the phase of the alternating potentials upon the control electrode 12 and anodes 11 to counteract the time delay may be obtained also by coupling the inductances 35 and 37 by a suitable time delay circuit such as a short transmission line 41, suitable stopping condensers 42 being connected in series with the line 41.

Although specific embodiments of this invention have been shown and described it will be understood, of course, 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 electron discharge device comprising a cathode, a plurality of anodes having juxtaposed end portions, control electrodes between said cathode and said anodes forming an opening in alignment with said cathode and said end portions, and means for focussing an electron beam from said opening upon said anodes including electrode elements disposed between said control electrodes and said anodes.

2. An electron discharge device comprising a cathode, a pair of anodes having juxtaposed end portions, an eccelerating electrode between said cathode and said anodes having an opening in alignment with said cathode and said end portions, means for focussing an electron beam from said cathode upon said opening, and control electrodes on opposite sides of said opening.

3. An electron discharge device comprising a cathode, a pair of anodes having juxtaposed end portions, an accelerating electrode between said cathode and said anodes and having an opening in alignment with said cathode and said end portions, means including an electrode between said cathode and said accelerating electrode for focussing an electron beam from said cathode upon said opening, means including an electrode between said accelerating electrode and said anodes for focussing said beam upon said anodes, and means including a control electrode between said accelerating electrode and said anodes for deflecting said beam alternately to said anodes.

4. An electron discharge device comprising a cathode including a plurality of filaments arranged in a plane, a plurality of pairs of anodes disposed substantially parallel to said plane, adjacent anodes having overlapping end portions, control means including a plurality of pairs of members disposed in a plane parallel to said cathode plane, the members of each pair being disposed on opposite sides of lines extending from cathode plane to said overlapping end portions, and an electrode between said members and said anodes for focusing electron beams upon said overlapping end portions.

5. An electron discharge device comprising a

cathode having a plurality of filaments disposed in a plane, a plurality of pairs of anodes disposed substantially parallel to said plane, adjacent anodes having overlapping end portions, control means between said cathode and said anodes including a plurality of pairs of members disposed in a plane parallel to said cathode plane and on opposite sides of normals extending from said cathode to said overlapping end portions, an accelerating electrode between said cathode and said control electrode having openings in alignment with said normals, an electrode between said cathode and said accelerating electrode for focussing electron beams upon said openings, and another electrode between said control electrode and said anodes for focussing said beams upon said overlapping end portions.

6. An electron discharge device comprising a cathode, a plurality of pairs of anodes disposed about said cathode and having juxtaposed end portions, control means including a plurality of pairs of members arranged in a cylindrical boundary coaxial with said cathode, the members of each of said pairs being positioned on opposite sides of radii extending from said cathode to said juxtaposed end portions, means directly connecting alternate anodes in electrical parallel, and means directly electrically connecting said members in two groups such that the electron beams impinging upon each of said anodes are substantially in phase.

7. An electron discharge device in accordance with claim 6 comprising an electrode between said members and said anodes for focussing electron beams upon said juxtaposed end portions, said focussing electrode including a plurality of members disposed on opposite sides of said radii and in a cylindrical boundary coaxial with said cathode.

8. An electron discharge device comprising a cathode, a plurality of pairs of arcuate anodes having overlapping end portions, arranged in a substantially cylindrical boundary coaxial with said cathode, control means including a plurality of pairs of members between said cathode and said anodes, lying in a cylindrical boundary coaxial with said cathode and disposed on opposite sides of radii extending from said cathode to said overlapping end portions, a cylindrical accelerating electrode between said cathode and said control electrodes and coaxial therewith, said accelerating electrode having openings in alignment with said radii, and an electrode for focussing electron beams from said openings upon said overlapping end portions including a plurality of members on opposite sides of said radii and lying in a cylindrical boundary coaxial with said cathode.

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