

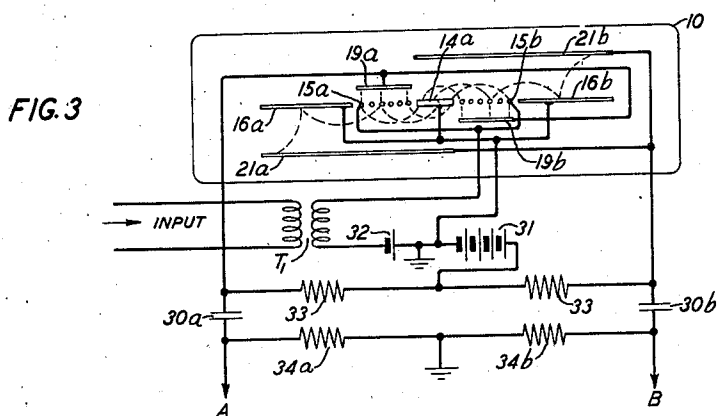
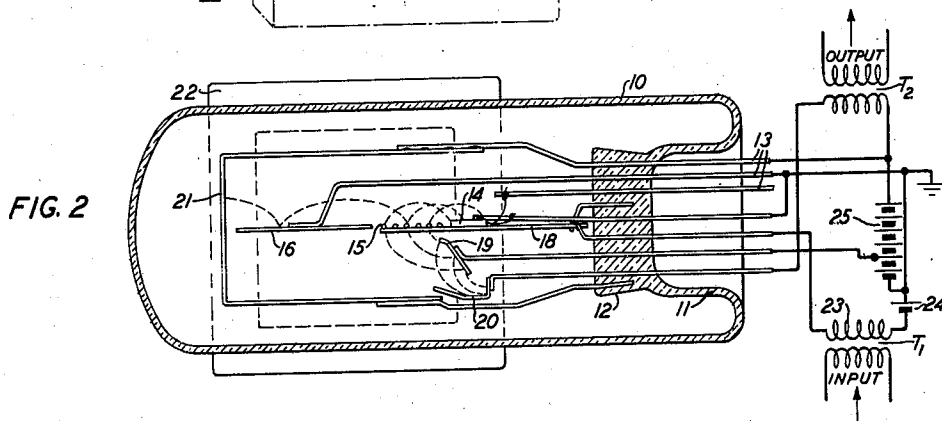
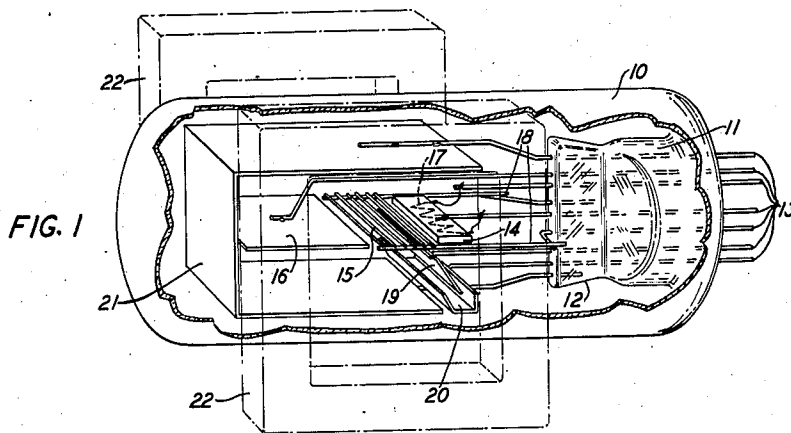
June 15, 1943.

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2,321,912

ELECTRON DISCHARGE APPARATUS

Filed Feb. 24, 1941



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2,321,912

ELECTRON DISCHARGE APPARATUS

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Application February 24, 1941, Serial No. 380,113

12 Claims. (Cl. 250—175)

This invention relates to electron discharge apparatus and more particularly to such apparatus especially suitable for operation at ultra high frequencies.

One object of this invention is to decrease the effective electron transit time in electron discharge devices whereby the frequency range of apparatus including such devices is extended.

Another object of this invention is to increase the transconductance of electron discharge devices.

A further object of this invention is to obtain extremely sensitive control of the electron current in electron discharge devices.

Still another object of this invention is to prevent contamination of the secondary electron emissive surfaces, in devices utilizing secondary emission, by the material of the primary electron source.

In one illustrative embodiment of this invention, electron discharge apparatus comprises a device including a source of primary electrons, for example a cathode, a control electrode or grid, a shield and a target electrode.

In accordance with one feature of this invention, the cathode, the control electrode or grid and the shield are mounted in coplanar relation, the control electrode or grid being positioned between the cathode and the shield, and means are provided for producing electrostatic and magnetic fields so related that the electrons emanating from the cathode are caused to traverse cycloidal paths having termini or cusps in the immediate vicinity of the control electrode or grid. A target electrode, which may be either an output anode or a secondary electron emissive member is mounted on the side of the control electrode or grid remote from that toward which the primary electrons flow. When a secondary electron emissive target electrode is employed, an output anode is mounted in cooperative relation therewith to collect the secondary electrons emanating therefrom.

The electrons emanating from the cathode traverse cycloidal paths having termini or cusps immediately adjacent the control electrode or grid and come to rest momentarily at this region. If the control electrode or grid is at zero potential or negative with respect to the cathode, the electrons traverse other cycloidal paths, without passing through the control electrode or grid, and are collected ultimately by a suitable electrode. However, if the control electrode or grid has impressed thereon a potential positive with respect to the cathode, some of the electrons, depend-

ing in number upon the magnitude of this potential, pass through the control electrode or grid and flow to the target electrode.

The invention and the foregoing and other 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 view in perspective of an electron discharge device and an associated magnetic field producing coil illustrative of one embodiment of this invention, the coil being shown in phantom and portions of the enclosing vessel of the device being broken away to show the internal elements of the device more clearly;

Fig. 2 is in part a side view partly in section of the apparatus shown in Fig. 1 and in part a circuit diagram illustrating one way in which the electron discharge device may be operated; and

Fig. 3 is a view, partly schematic and partly diagrammatic, illustrating another embodiment of this invention.

Referring now to the drawing, the electron discharge device illustrated in Figs. 1 and 2 comprises an evacuated enclosing vessel 10 having a stem 11 in the press 12 of which a plurality of leading-in conductors 13 are sealed. Mounted within the enclosing vessel 10 and supported by the appropriate leading-in conductors 13 are a rectangular cathode 14, a control electrode or grid 15 and a shield electrode 16, these electrodes being substantially coplanar, as shown clearly in Fig. 2, and the control electrode or grid 15 being located between the cathode 14 and the shield electrode 16. In the particular embodiment shown in Figs. 1 and 2, the cathode 14 is of the equipotential indirectly heated type and includes a relatively thin metallic shell which encloses a heater filament 17 and one surface of which, for example, the upper face in Figs. 1 and 2, is coated with a material having good thermionic emission characteristics. Although an indirectly heated cathode has been shown, it will be understood that other types may be employed. For example, a ribbon or filamentary cathode may be employed or a plate having a photoelectric emissive surface may be utilized, this surface being energized by a suitable beam of light played thereon.

The control electrode or grid 15 comprises a plurality of equally spaced parallel wires extending parallel to the longer dimension of the cathode 14 and supported by a pair of rigid wires 18 affixed to two of the leading-in conductors 13.

Mounted in proximity to the control electrode

or grid 15 on the side thereof remote from the emissive surface of the cathode 14 is a target electrode 19, which may be a metallic plate the surface of which toward the control electrode or grid is coated with a material having good secondary electron emissive characteristics. Opposite the target electrode 19 is an output anode or collector electrode 20, which may be trough shaped as shown. If desired, the target electrode 19 may be provided with an integral grid portion, not shown, parallel to the control grid for increasing the shielding between the latter and the anode.

The cathode, control electrode or grid and shield are embraced by a U-shaped accelerating electrode 21 the arms of which, as shown clearly in Fig. 2, are parallel to and equally spaced from the electrodes mentioned.

During operation of the device a strong magnetic field is produced having its lines of force parallel to the plane of the cathode, control electrode or grid and shield and normal to the longitudinal axis of the enclosing vessel 10. This field may be produced, in one embodiment, by a two part coil 22 the two sections of which are mounted in alignment on opposite sides of the enclosing vessel. Alternatively, the field may be produced by a permanent or electromagnet having its poles on opposite sides of the enclosing vessel and in juxtaposition to the coplanar electrodes.

The electron discharge device illustrated in Figs. 1 and 2 may be operated as an amplifier, oscillator or rectifier and may be included in a variety of circuits. In a particular and illustrative application shown in Fig. 2, the device is associated with suitable circuit elements for operation as an amplifier. The control electrode or grid 15 is connected to the cathode 14 through the secondary winding 23 of an input transformer T₁ and a source, such as a battery 24 for applying a suitable biasing potential, for example of the order of 1.5 volts negative with respect to the cathode, and the output anode or collector electrode 20 is connected to the cathode through the primary winding of an output transformer T₂ in series with a source, such as a battery 25, for maintaining the anode or collector electrode 20 at a positive potential, for example of the order of 200 volts, with respect to the cathode. The target electrode 19 and accelerating anode 21 are maintained at positive potentials, for example of the order of 100 volts and 200 volts respectively, by appropriate connections to the battery 25. The shield 16 may be operated at cathode potential as shown.

The primary electrons emanating from the cathode 14 come under the influence of two fields, namely, the electric field due to the positive potential of the accelerating anode 21 and the magnetic field produced by the coil 22. These fields, as will be apparent, are crossed, i. e., have their lines at substantially right angles to one another, so that when the fields are properly correlated in intensity the electrons emanating from the cathode 14 traverse cycloidal paths, indicated by the dotted lines between the cathode and the control electrode in Fig. 2, and flow to points immediately adjacent to the control electrode or grid in which region they come to rest momentarily.

If the control grid is at cathode potential or negative with respect to the cathode, the electrons leave this region and, without passing through the control electrode or grid, follow substantially cycloidal paths, one of which is

indicated by the broken line to the left of the grid 15 in Fig. 2, and arrive ultimately at the accelerating anode 21. If, however, the control electrode or grid 15 becomes positive with respect to the cathode, as by the application of a signaling potential thereto, electrons are drawn from the region immediately adjacent the control electrode or grid, pass through the control electrode or grid and impinge upon the target electrode 19, the number of electrons so drawn at any instant being proportional to the potential of the grid at that instant. The electrons impinging upon the target electrode 19 cause the release of secondary electrons, in number greater than the impinging electrons, which are collected by the output anode or collector electrode 20 and constitute the output current of the device.

It will be noted that when the discharge device is thus operated, a dense cloud of electrons having small velocities is produced in the region immediately adjacent the control electrode or grid 15 whereby a dense space charge region or virtual cathode is formed in this region. Because of the low velocity of the electrons and the proximity of the virtual cathode to the control electrode or grid, extremely sensitive control of the electron current to the target electrode is realized and a high transconductance is attained. Furthermore, it will be appreciated that the effective electron transit time is the time of flight between the dense space charge or virtual cathode region and the target electrode so that, inasmuch as the target electrode may be mounted but a short distance from the control electrode or grid, extremely short transit times may be achieved and operation at ultra-high frequencies, for example in the centimeter range of wave-lengths, is obtainable. Moreover, it will be noted that the electron current to the target electrode may be cut off effectively with a relatively small change in the potential of the grid. It will be noted also that the target electrode 19 is effectively shielded from the emissive surface of the cathode 14 so that the secondary electron emissive surface thereof is protected against contamination by such material as may be evaporated from the emissive surface of the cathode during operation of the device.

It will be understood that the target electrode 19 need not be secondary electron emissive in which case it would serve as the output anode of the device. On the other hand, one or more additional secondary electron emissive electrodes may be employed between the target electrode 19 and the collector electrode 20 to constitute, with the target and collector electrodes, a multistage electron multiplier whereby additional amplification of the signal impressed upon the control electrode or grid 15 is obtained.

The electron discharge device shown in Fig. 3 is illustrative of another embodiment of the invention and is especially suitable for use as a push-pull amplifier. It comprises generally the same elements as the device illustrated in Figs. 1 and 2 and is of substantially the same construction as the elements shown in the both figures. To simplify the drawing the magnetic field producing coil is not shown in Fig. 3. Specifically, it includes a pair of control electrodes or grids 15a and 15b coplanar with the cathode 14a, a pair of shields 16a and 16b also coplanar with the cathode 14a, a pair of non-emissive target electrodes 19a and 19b, each mounted opposite one of the control electrodes or grids 15a and 15b, and a pair of plate-like accelerating anodes

21a and 21b mounted parallel to the other electrodes. The cathode 14a may be of the same construction as the cathode shown in Figs. 1 and 2, or of the other types mentioned heretofore, except that both of its major faces are electron emissive. Means, such as coils, not shown, similar to the coils 22 in Figs. 1 and 2, are provided for producing a magnetic field having its lines of force parallel to the plane of the coplanar electrodes and normal to the longitudinal axis of the enclosing vessel 10.

The operation of the apparatus shown in Fig. 3 as an amplifier is similar to that of the apparatus illustrated in Fig. 2 and described heretofore. It may be noted, however, that the two target electrodes 19a and 19b are connected together and to a suitable blocking condenser 30a, and serve as output anodes. The accelerating electrodes 21a and 21b also function as output anodes and are connected together and to a blocking condenser 30b. The target and accelerating electrodes may be maintained at the same positive potential with respect to the cathode 14a as by a battery 31 connected to the electrodes through equal resistances 33. The shields 16a and 16b may be operated at cathode or ground potential as shown.

A suitable input circuit, including the secondary winding of an input transformer T₁ and a battery 32 for applying an appropriate biasing potential to the control electrodes or grids 15a and 15b, may be associated with these control electrodes or grids and the cathode 14a as shown in the drawing. An output circuit may be connected across the output resistors 34a and 34b, the center point of which is grounded.

The electrons emanating from the opposite emissive surfaces of the cathode 14a constitute two equal electron currents and, under the influence of the crossed magnetic and electron fields, flow to regions immediately adjacent the control electrodes or grids 15a and 15b as described heretofore in connection with Figs. 1 and 2, the electron trajectories being cycloidal as illustrated by the dotted lines in Fig. 3. Hence, two regions of dense space charge or virtual cathodes are produced, one adjacent each of the control electrodes or grids 15a and 15b. The potential of the grids 15a and 15b is made such that with no signal upon the transformer T₁, the electron currents divide equally between each target electrode 19 and the corresponding anode 21. The subsequent division of the electrons depends, as in the device shown in Figs. 1 and 2, upon the potential of the grids. When a signal is applied to the transformer T₁, the potential of the grids varies accordingly. When the grid potential becomes more positive, more electrons are drawn through the grids and flow to the target electrodes. When the potential of the grid becomes more negative, relative to the cathode the electron currents to the target electrodes 19 decrease and those to the anodes 21 increase. Hence, the potential drops across the resistances 34a and 34b vary in accordance with the signal. The output terminals A and B may be connected to a load device or, as will be apparent, may be connected to the input terminals of a push-pull amplifier.

Although specific embodiments of the 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. Electron discharge apparatus comprising a cathode, an apertured signal control electrode having opposite surfaces, means adjacent the region between said cathode and one surface of said control electrode for producing in said region magnetic and electric fields mutually related to direct electrons emanating from said cathode along curved paths having termini immediately adjacent said one surface, and a target electrode opposite the other of said surfaces.

2. Electron discharge apparatus comprising a cathode, an apertured signal control electrode adjacent said cathode and having opposite surfaces, directing means for directing electrons emanating from said cathode along curved paths having termini immediately adjacent one of said surfaces, and an output anode opposite the other of said surfaces, said directing means including an accelerating anode opposite said one surface and a magnetic field producer opposite said cathode and said control electrode.

3. Electron discharge apparatus comprising a cathode having a substantially plane electron emissive surface, a substantially plane signal control grid mounted in edge-to-edge relation and substantially coplanar with and wholly to one side of said emissive surface, means for directing electrons emanating from said cathode along cycloidal paths having termini immediately adjacent one face of said control electrode, said means including a magnetic field producer adjacent said cathode and said control electrode and having the direction of its field substantially parallel to the plane common to said emissive surface and said control electrode, and an electron receiving electrode opposite the other face of said control electrode.

4. Electron discharge apparatus comprising a cathode, a shield electrode, a signal control grid mounted to one side of and substantially coplanar with said cathode and between said cathode and said shield electrode, electrode and magnetic means in cooperative relation with said cathode and control electrode for concentrating electrons emanating from said cathode into a stream flowing toward said control electrode and having substantially zero velocity in a region immediately adjacent one surface of said control grid, and an electron receiving electrode opposite said control electrode.

5. Electron discharge apparatus comprising a substantially linear cathode, a shield electrode substantially coplanar with said cathode, an apertured signal control grid having opposite surfaces and mounted between, in edge-to-edge relation to and substantially coplanar with said cathode and said shield electrode, means for directing electrons emanating from said cathode along cycloidal paths having termini immediately adjacent one surface of said control electrode, said means including an accelerating anode opposite said cathode and said one surface and means adjacent said cathode and control electrode for producing a magnetic field in the region thereadjacent, and a target electrode opposite the other surface of said control electrode.

6. Electron discharge apparatus comprising a cathode having a substantially plane electron emissive surface, a shield substantially coplanar with said surface, a signal control grid between said cathode surface and said shield, in edge to edge relation thereto and substantially coplanar therewith, an accelerating anode including portions on opposite sides of said cathode, grid and

shield and parallel thereto, means adjacent said cathode and said control grid for producing a magnetic field adjacent said cathode and grid, parallel thereto and normal to the electron path therebetween, and a target electrode opposite the face of said grid remote from said electron emissive surface.

7. Electron discharge apparatus in accordance with claim 6 wherein said target electrode is secondary electron emissive and which comprises an output anode in spaced relation from the plane of said shield.

8. Electron discharge apparatus comprising a cathode, a pair of signal control electrodes each having opposite faces, said control electrodes being mounted on opposite sides of said cathode in edge-to-edge relation thereto and substantially coplanar therewith, means adjacent said cathode and said control grid for concentrating electrons emanating from said cathode into two streams each of which traverses an arcuate path having a terminus immediately adjacent one surface of one of said control electrodes, and a pair of target electrodes each mounted opposite the opposite surface of the corresponding one of said control electrodes.

9. Electron discharge apparatus in accordance with claim 8 comprising a pair of anodes, each anode being opposite said coplanar control electrodes.

10. Electron discharge apparatus comprising a

substantially plane cathode, a pair of substantially plane signal control grids on opposite sides of said cathode and substantially coplanar therewith, a pair of anodes each opposite one face of a corresponding one of said grids, and electrode and magnetic means adjacent said cathode and said grids for directing electrons emanating from said cathode along two groups of cycloidal paths each of which groups has termini immediately adjacent the face of one of said grids opposite said one face thereof.

11. Electron discharge apparatus in accordance with claim 10 comprising a second pair of anodes, each anode of said second pair being opposite said coplanar control grids.

12. Electron discharge apparatus comprising a cathode having opposite faces thereof electron emissive, a pair of shields on opposite sides of said cathode and substantially coplanar therewith, a pair of control grids on opposite sides of said cathode and substantially coplanar therewith, each grid being mounted between said cathode and one of said shields, a pair of anodes mounted in juxtaposition to opposite faces of one of said grids, a second pair of anodes mounted in juxtaposition to opposite faces of the other of said grids, and means for producing a magnetic field adjacent said cathode and grids, parallel thereto and normal to the electron path therebetween.

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