June 11, 1946. W. G. SHEPHERD 2,401,777

ELECTRON DISCHARGE APPARATUS

Filed Sept. 5, 1941

FIG. 1

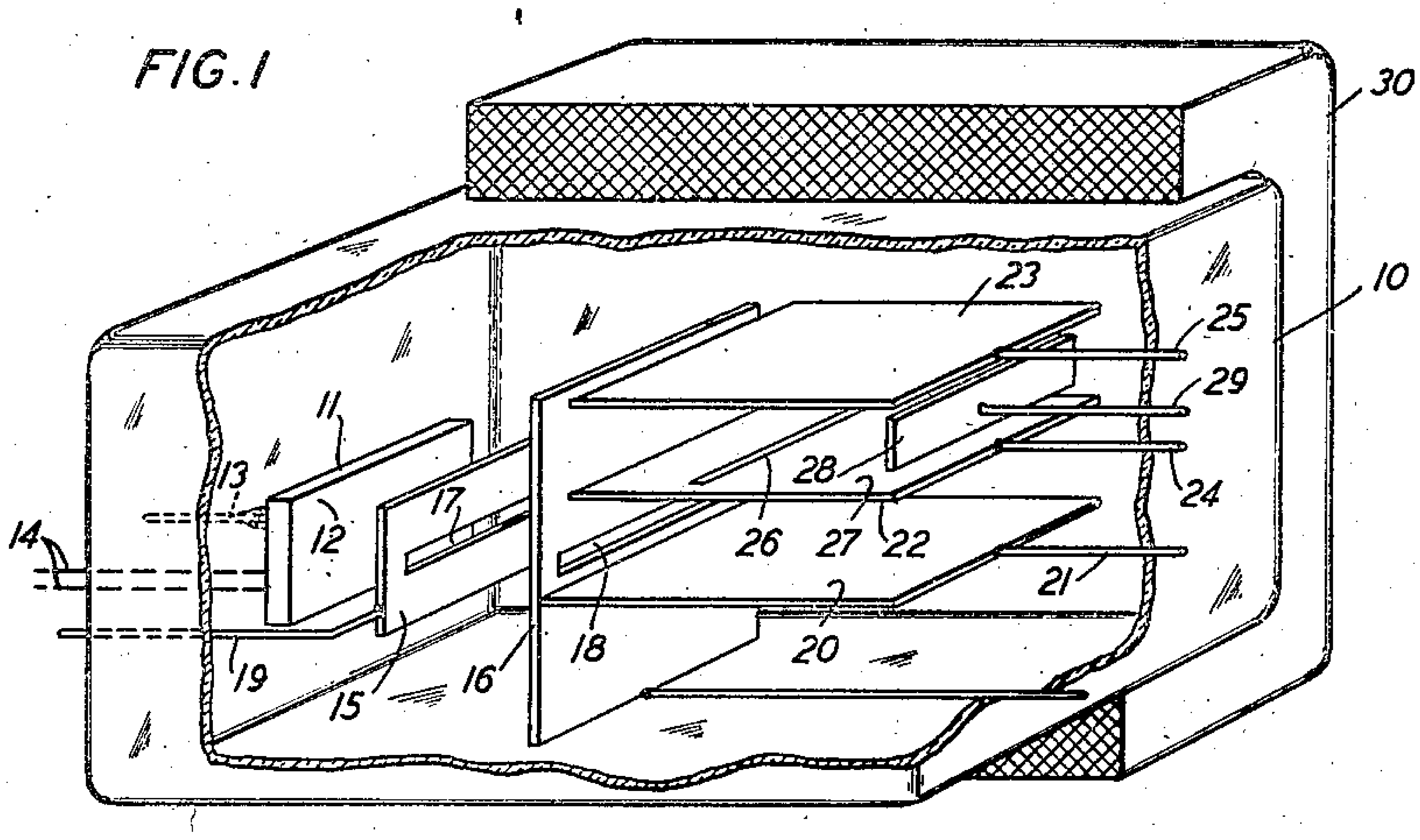


FIG. 2

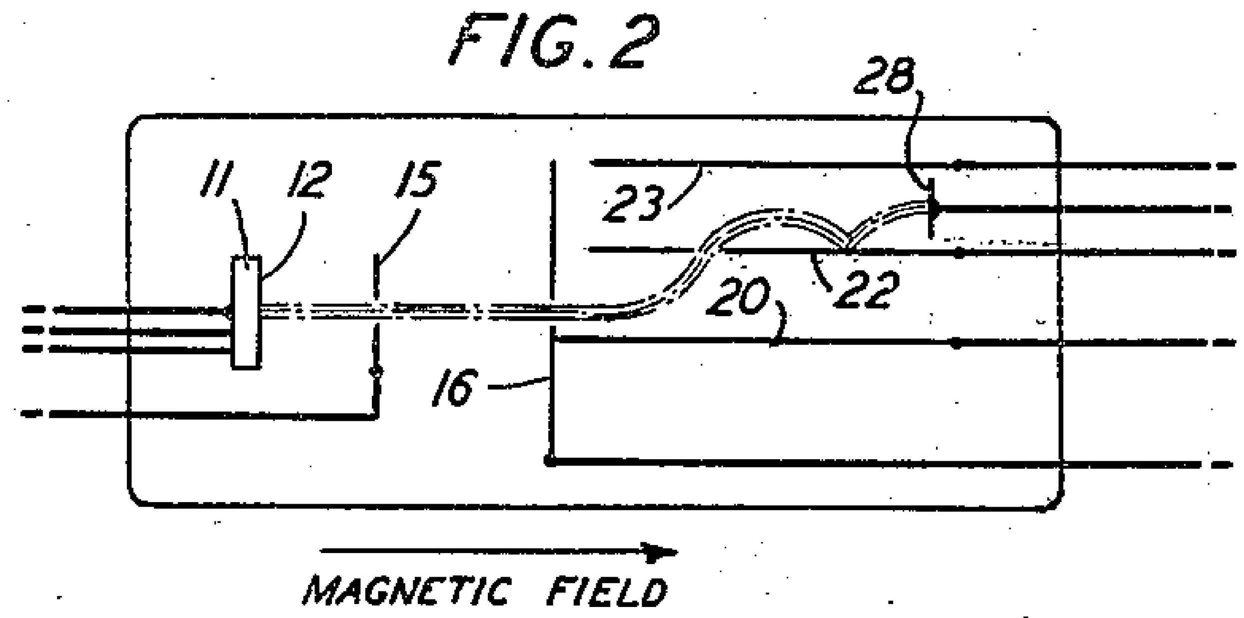
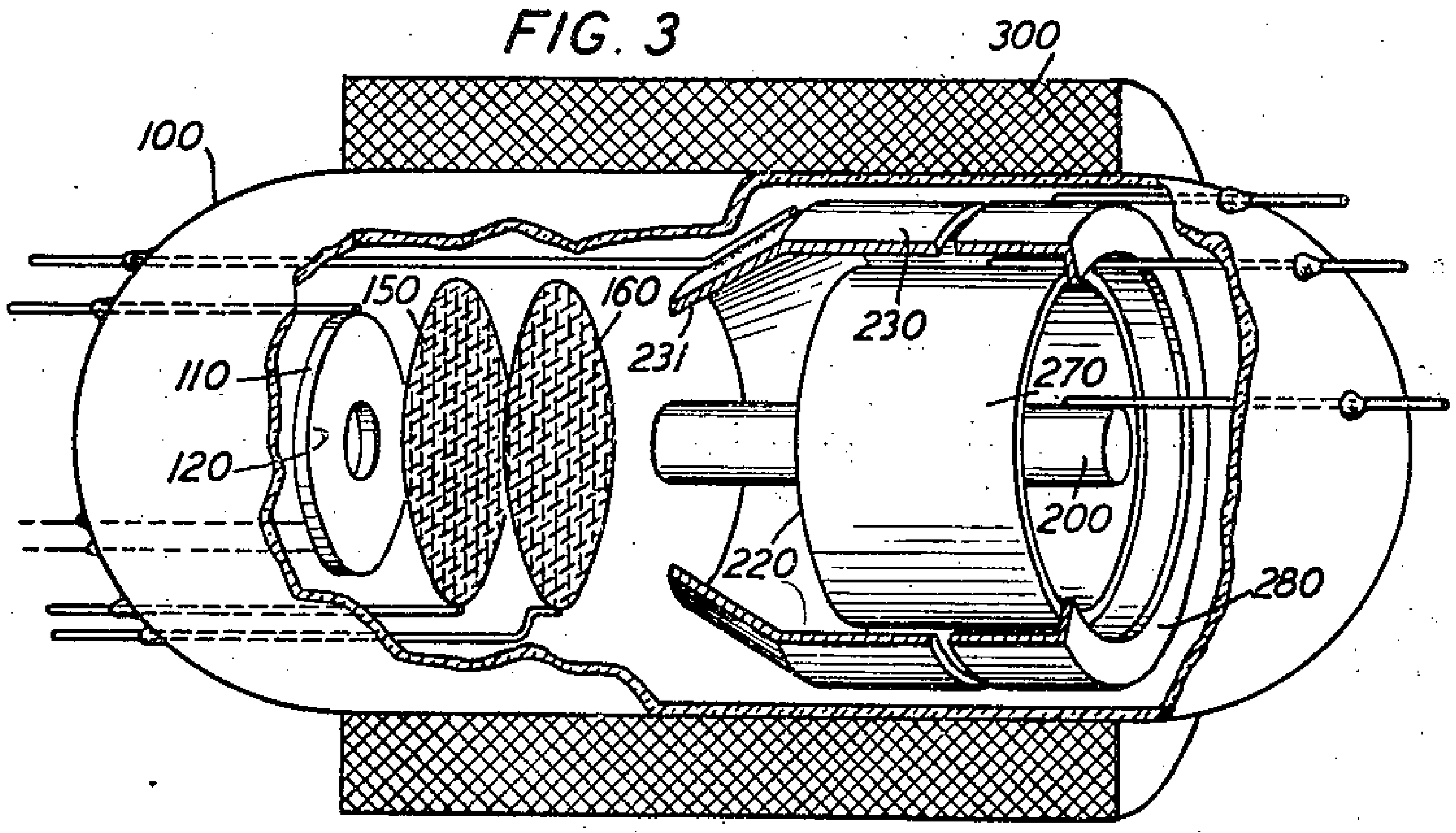


FIG. 3



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ELECTRON DISCHARGE APPARATUS

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8 Claims. (Cl. 250—174)

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This invention relates to electron discharge apparatus and more particularly to electron discharge devices especially suitable for use as high frequency or feedback amplifiers and including a secondary electron emissive target or electrode in cooperative relation with the output electrode.

The use of a secondary electron emissive electrode in cooperative relation with the output electrode of an electron discharge device enables the realization of relatively high transconductances. The attainment of stable operating characteristics and long life for such a device entails shielding of the secondary electron emissive surface to prevent contamination thereof by material evaporated from the primary cathode. This, in turn, has entailed heretofore the direction of the primary electrons along relatively long curved paths in flowing to the secondary electron emissive surface. It has been found that, as a result, in such devices the electron transit time is higher than in more conventional devices not utilizing secondary emission and as a consequence the amount of feedback obtainable was less than with more conventional devices.

One object of this invention is to increase the feedback obtainable in electron discharge devices including a secondary electron emissive target or electrode. More specifically, one object of this invention is to obtain both effective shielding of the secondary electron emissive target or electrode and a low electron transit time in such devices.

In one illustrative embodiment of this invention, an electron discharge device comprises a primary cathode and control and accelerating electrodes for producing an electron stream, a target electrode having a secondary electron emissive surface against which the primary electron stream is directed, and a collector or output electrode in cooperative relation with the secondary electron emissive surface.

In accordance with one feature of this invention, the secondary electron emissive electrode is an apertured member the emissive surface of which extends generally in the direction of projection of the primary electron stream, the electrode being mounted adjacent the path of the projected primary electron stream and having its emissive surface remote therefrom, and means are provided for producing cooperating electric and magnetic fields adjacent this electrode such that the primary electrons are directed along paths passing through the aperture in the electrode and terminating at the secondary electron emissive surface.

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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 drawing in which:

Fig. 1 is a perspective view of electron discharge apparatus illustrative of one embodiment of this invention, a portion of the field coil and of the enclosing vessel of the discharge device being broken away to show the electrodes of the device more clearly;

Fig. 2 is a diagrammatic side view of the apparatus illustrated in Fig. 1 showing the relation of the electrodes and indicating the electron paths; and

Fig. 3 is a perspective view of electron discharge apparatus, portions of which are broken away for the sake of clarity, illustrative of another embodiment of this invention wherein the electrodes of the device are mounted in coaxial relation.

Referring now to the drawing, the electron discharge apparatus illustrated in Figs. 1 and 2 comprises an evacuated enclosing vessel 10, for example of glass, adjacent one end of which there is mounted a cathode 11, for example of the equipotential indirectly heated type, having a rectangular electron emissive surface 12 extending normal to the longitudinal axis of the enclosing vessel 10. The cathode may be supported by a leading-in conductor 13 sealed to one end wall of the enclosing vessel, in which wall the leading-in conductors 14 for the cathode heater element, not shown, also are sealed.

Mounted opposite the cathode emissive surface 12 and parallel thereto are a control electrode 15 and an accelerating electrode 16. The control and accelerating electrodes may be grids or may be plates having aligned, parallel slots or apertures 17 and 18, respectively, the control electrode being supported by a leading-in conductor 19. Extending normal to the accelerating electrode 16 from adjacent the aperture 18 is a metallic plate member 20, which may be secured to the electrode 16 as shown and is supported by a leading-in conductor 21.

A pair of plate electrodes 22 and 23 are mounted parallel to the plate member 20, as by leading-in conductors 24 and 25 respectively, the electrode 22 having an elongated aperture or slot 26 therein and having the surface 27 thereof remote from the plate member 20 coated with a material having good secondary electron emissive properties. Mounted between the electrodes 22 and 23 is a collector or output electrode 28 which may be supported by a leading-in conductor 29.

The enclosing vessel is encompassed by a coil 30 capable of producing a strong magnetic field having its lines of force parallel to the longitudinal axis of the enclosing vessel 10.

During operation of the device, the accelerating electrode 16 is maintained at a positive potential with respect to the cathode 11 so that an electron stream, which is concentrated by the magnetic field produced by the coil 30, is projected through the aperture 18 into the region between the plate members 20 and 22. The intensity of the stream may be controlled or modulated by suitable potentials applied between the control electrode 15 and cathode 11. The electrode 22 is maintained at a positive potential with respect to the plate member 20. The electrons issuing from the aperture 18, then, are projected into a region wherein crossed magnetic and electric fields, that is, the magnetic field parallel to the direction of projection of the electron stream, i. e., parallel to the longitudinal axis of the vessel 10, and an electric field normal to this direction, i. e., normal to the planes of the electrode 22 and plate member 20, exists. Consequently, the electrons are directed along paths, the projection of which on a plane normal to the direction of projection of the primary electron stream is a cycloid or trochoid, passing through the aperture 26 and enter into the space between the electrodes 22 and 23. The electrode 23 may be operated at the same potential as the electrode 22 so that the electrons flowing through the aperture 26 are projected into an electrostatically field free space. Because of the magnetic field which is present between the electrodes 22 and 23 and the velocity normal to this field which the electrons have acquired, however, these electrons will be directed along curved paths and caused to impinge upon the surface 27 of the electrode 22 whereby secondary electrons greater in number than the electrons impinging upon the surface 27 are released. These secondary electrons flow to the collector electrode 28, which is at a higher positive potential than the electrode 22, and constitute the output current. The electron paths are indicated by the broken lines in Fig. 2.

In another mode of operation, the electrode 23 is maintained at a higher positive potential than the electrode 22, most favorably at a potential corresponding to a linear variation of potential from the plate member 20 to the electrode 23, so that the secondary electrons emanating from the surface 27 are drawn to and collected by the electrode 23. In this case, the electrode 23 serves as the output electrode and the collector electrode 28 may be omitted.

It will be noted that, inasmuch as the magnetic field is in the direction of projection of the primary electron stream into the region between the plate member 20 and the target electrode 22, it will have no material effect upon either the electron transit time between the cathode 11 and this region, or the transconductance of the device. Furthermore, it will be apparent that the electron paths between the aperture 18 and the secondary electron emissive surface 27 may be made short so that the electron transit time between this aperture and surface is small. Hence, the total electron transit time in the device will be small. Finally, it will be noted that the secondary electron emissive surface 27 is highly shielded from the emissive surface 12 of the cathode 11 so that contamination of the surface 27 by material evaporated from the surface 12 is prevented.

In the case described above where the electrodes 22 and 23 are operated at the same potential and the collector electrode 28 is employed as the output electrode, the primary electrons passing through the aperture 26 and flowing to the surface 27 are traveling in electrostatically field free space so that their transit time in flowing from the aperture 26 to the surface 27 may be made very small.

The embodiment of this invention illustrated in Fig. 3 is generally the same as that shown in Figs. 1 and 2 except that a coaxial electrode system is employed. It comprises an enclosing vessel 100, an annular cathode 110 having an emissive surface 120, and control and accelerating grids 150 and 160 respectively for projecting a hollow cylindrical electron stream, concentrated by the magnetic field due to the coil 300, toward the coaxial electrodes 200, 220, and 230, the latter of which has a frusto-conical portion 231 and the electrode 220 having its outer surface 270 treated or coated so that copious secondary electron emission is obtainable therefrom.

The electrode 230 is maintained at a positive potential with respect to the central electrode 200 and the collector electrode 280 is maintained at a positive potential with respect to the secondary electron emissive electrode 220. The cylindrical electron beam enters into a region between the electrodes 200 and 230 and thus comes under the influence of the radial electric field between these electrodes, which field is substantially normal to the magnetic field due to the coil 300. Consequently, the primary electrons constituting the beam are directed along curved paths and impinge upon the emissive surface 270 to cause the release of secondary electrons therefrom. The secondary electrons thus produced flow to the collector electrode 280 and constitute the output current of the device.

In addition to having the advantages of high transconductance, low transit times and shielding of the secondary emissive surface of the device disclosed in Fig. 1, the device illustrated in Fig. 3 is characterized by very small stray capacitances and feasibility of association with coaxial transmission lines. Although in Fig. 3 the various electrode leading-in conductors are shown as wires, they may be coaxial conductors whereby association of the device with external coaxial lines is facilitated and matching of the characteristic impedance of the internal and external elements of the input and output circuits is enabled.

Although the invention has been illustrated in single stage devices, it may be embodied also in devices adapted for push-pull operation, in which case the cathode would have both of its surfaces electron emissive and similar electrode systems, symmetrical with respect to the cathode would be associated with the cathode. Also, although coils have been shown for producing the requisite magnetic field, permanent magnets may be utilized for this purpose. Other modifications may be made, of course, in the specific embodiments shown and described 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 an electrode having an aperture therein and having

also an electron emissive surface, a collector electrode in electron receiving relation with said emissive surface, means for projecting an an electron stream adjacent said first electrode substantially parallel to said surface and on the side of said first electrode remote from said emissive surface, and means adjacent said first electrode for directing said electron stream along a curved trajectory passing through said aperture and for directing the stream passing through said aperture against said electron emissive surface.

2. Electron discharge apparatus in accordance with claim 1 wherein said directing means comprises electrode means for producing an electric field substantially normal to said surface and means for producing a magnetic field substantially parallel to said surface.

3. Electron discharge apparatus comprising a pair of plane parallel electrodes, one of said electrodes having an aperture therein and having a secondary electron emissive coating on the surface thereof remote from the other of said electrodes, a collector electrode in electron receiving relation with the coated surface of said one electrode, leads connected to said pair of electrodes for establishing an electric field between said pair of electrodes and substantially normal to the surfaces thereof, means mounted to one side of said pair of electrodes for projecting an electron stream between said pair of electrodes and substantially parallel to the surfaces thereof, and means adjacent said pair of electrodes for producing a magnetic field therebetween and having its lines of force substantially normal to said electric field.

4. An electron discharge device comprising an electrode having an aperture therein, means for projecting a stream of primary electrons through said aperture, a plate electrode extending from adjacent said first electrode, at an angle thereto and to one side of said aperture, said plate electrode having a coating of secondary electron emissive material on the face thereof remote from said aperture and having also an aperture therein, a collector electrode in electron receiving relation with said coating, and means including electrode members adjacent said first electrode for directing electrons emanating from said first aperture, through said second aperture and against said coating.

5. Electron discharge apparatus comprising a cylindrical electrode having its outer surface secondary electron emissive, a collector electrode in cooperative relation with said surface, means for projecting a stream of electrons toward said cylindrical electrode and parallel to the longitudinal axis thereof, and means for directing said electron stream along curved paths adjacent said cylindrical electrode and against said surface, said means including cylindrical field electrodes within and outside of said cylindrical electrode and coaxial therewith and means for producing a magnetic field adjacent said cylindrical electrode and having its lines of force substantially parallel to the longitudinal axis of said cylindrical electrode.

6. Electron discharge apparatus comprising an electrode having an aperture therein, secondary electron emissive means on one side of said electrode, a collector electrode in electron receiving relation with said emissive means, means for projecting an electron stream into a region on the opposite side of said electrode and in a direction at an angle to an axis passing through said aperture, and means adjacent said first electrode for directing electrons from said region along curved paths passing through said aperture and terminating at said emissive means.

7. Electron discharge apparatus in accordance with claim 6 wherein said directing means includes means for producing a magnetic field adjacent said first electrode and said emissive means and having its lines of force parallel to the direction of projection of said stream and includes also electrode means adapted when energized to produce in said region an electric field substantially normal to said magnetic field.

8. Electron discharge apparatus comprising an electrode having a secondary electron emissive surface, means for projecting an electron stream toward said electrode and along a linear path substantially parallel to said emissive surface, means for producing a magnetic field along and parallel to said path and adjacent said electrode, electrode means adjacent said first electrode and adapted when energized to produce adjacent said electrode an electric field substantially normal to said magnetic field whereby, adjacent said electrode, said stream is directed along a curved path terminating at said emissive surface, and a collector electrode in electron receiving relation with said emissive surface.

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