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ELECTRON DISCHARGE DEVICE

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FIG. 1

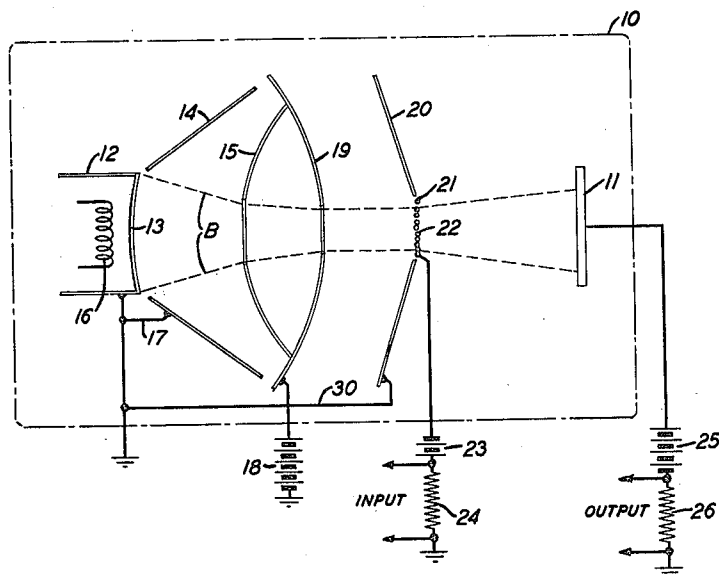
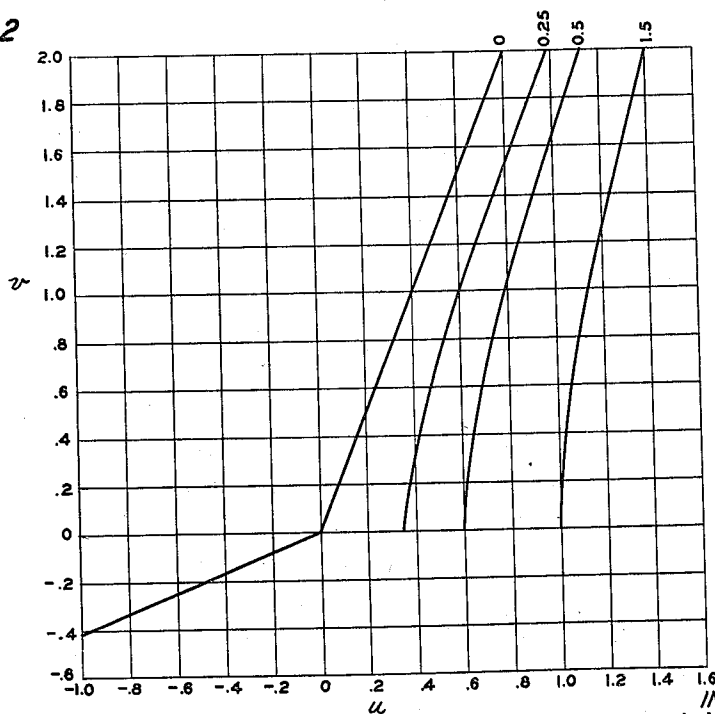


FIG. 2



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ELECTRON DISCHARGE DEVICE

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7 Claims. (Cl. 250—27)

This invention relates to electron discharge devices and more particularly to such devices of the electron beam and virtual cathode types.

One general object of this invention is to improve the operating characteristics and efficiency of electron beam discharge devices. More specifically, objects of this invention are to:

Expedite the attainment of high current density electron beams in electron discharge devices;

Facilitate the production of a virtual cathode in electron discharge devices;

Improve the operating stability of devices of the virtual cathode type;

Increase the transconductance of electron discharge devices; and

Reduce the conduction current to the control electrode or grid in such devices.

In one illustrative embodiment of this invention, an electron discharge device comprises an anode or target electrode, an electron gun for projecting an electron beam toward the target electrode, and an electrode system between the electron gun and the target electrode or anode.

In accordance with one feature of this invention, the electrode system comprises a pair of spaced, aligned, centrally apertured electrode members so constructed and arranged and related to the electron gun that in the region between the two members the electrons in the beam are directed along parallel paths, and when the electrodes are energized a potential zero is established immediately adjacent the electrode member furthest removed from the electron gun whereby a virtual cathode is produced immediately adjacent the aperture in this electrode member.

In accordance with another feature of this invention, a control electrode or grid is mounted within or in the immediate vicinity of the aperture in the electrode member furthest removed from the electron gun, this electrode or grid being effective to vary greatly the current transmitted through this aperture, in accordance with relatively small changes in its potential.

In accordance with a further feature of this invention, the control electrode is a wire frame or ring in close proximity to the boundary of the aperture mentioned whereby, when this electrode is positive and electron current is transmitted through the aperture, the electrode is effective to increase the focussing of the beam and thus the conduction current to this electrode is very small.

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 diagrammatic view of an electron discharge device illustrative of one embodiment of this invention; and

Fig. 2 is a graph illustrating appropriate forms of the electrode members in the device shown in Fig. 1.

Referring now to the drawing, the electron discharge device illustrated in Fig. 1 comprises an evacuated enclosing vessel 10, shown in phantom, within which there are mounted an anode or target electrode 11 and an electron gun for producing a concentrated sheet-like electron stream which is projected toward the anode or target electrode 11. The electron gun, which may be of the construction disclosed in the application Serial No. 307,233, filed December 2, 1939, of John R. Pierce, comprises a cathode 12 having a dished electron emissive surface 13 and a pair of aligned, centrally apertured beam forming electrodes 14 and 15, the electrode 14 extending from adjacent the periphery of the emissive surface 13 and the electrode 15 being dished toward the cathode. As shown, the cathode may be of equipotential type and comprise a heater filament 16. The electrode 14 may be connected to the cathode, for example, directly by a conductor 17, the cathode may be at ground potential, and the electrode 15 may be maintained at a positive potential with respect to the cathode 12 by a suitable source, such as a battery 18.

Mounted between the electron gun and the anode or target electrode 11 and in alignment therewith are a pair of centrally apertured electrodes 19 and 20. The electrode 19 may be integral with the electrode 15 as shown, so that it is maintained at the same potential as the electrode 15, and the electrode 20 may be operated at cathode potential, being connected to the cathode, for example, by a conductor 30.

A control electrode or grid is mounted within the aperture in the electrode 20 and, in one form, includes a wire frame 21 and a grid or reticulated portion 22. The control grid is biased at a negative potential with respect to the cathode, as by a battery 23, and its potential may be varied in accordance with a signal impressed across the input resistor 24.

The anode or target electrode 11 is operated at a positive potential with respect to the cathode, as by a battery 25 in series with the output resistor 26.

The electrons emanating from the emissive surface 13 are concentrated into a converging

sheet beam, the boundaries of which are indicated by the broken lines B, which is projected through and substantially fills the aperture in the electrode 15, traverses the region between the electrodes 15 and 19 and emerges from the aperture in the latter electrode. The apertures in the electrodes 15 and 19 are made such, in accordance with known principles, that the lens actions thereof result in parallel electron flow, parallel to the axis of alignment of the electrodes, at the aperture in the electrode 19. Hence, at the region of entry of the electrons into the space between the electrodes 19 and 20, the electron flow is parallel to the axis of alignment of the electrodes.

The electrodes 19 and 20 are so constructed and arranged that in the region therebetween the electrons are directed along parallel paths between boundaries passing immediately adjacent the edges of the electrode 20 bounding the aperture therein. The principles involved in such construction and arrangement are set forth fully in the application Serial No. 416,778, filed October 28, 1941, of John R. Pierce. It will be noted, however, that the electrodes 19, 20 and 11 constitute an electrode system wherein the end electrodes 19 and 11 are at positive potentials and in which the potential distribution is such that a potential zero exists at the plane of the aperture in the electrode 20. The electrodes 19 and 21, then, are of the form given by the relation

$$u+iv=(\Phi+i\Psi)^{3/4}$$

where u and v are the rectangular coordinates of each electrode, v being taken normal to the electron flow and equal to zero at the beam boundary, Φ is a constant proportional to the potential of the electrode $i=\sqrt{-1}$, and Ψ is a complementary function. Several appropriate configurations of the electrodes 19 and 20 for various values of Φ are shown in Fig. 2.

The electrons emanating from the aperture in the electrode 19 flow along parallel paths toward the aperture in the electrode 20. When the control grid 21, 22 is at a negative potential, all of the electrons come to rest momentarily adjacent the control grid, whereby a virtual cathode is established, and are reflected toward the electrode 19. However, when the control grid becomes positive, as in accordance with an input signal impressed across the resistor 24, the electrons, in number determined by the potential of the control grid, will pass through the control grid and flow to the target electrode or anode 11.

It will be appreciated that the electrodes 15 and 19 may be operated at high positive potentials with respect to the cathode 12 so that large currents may be drawn from the cathode and a virtual cathode of high current capacity thus realized in the immediate vicinity of the control grid. It will be noted also that the electrons transmitted through the control grid leave the region thereof with low velocities so that divergence of the electron stream due to space charge effects, is small in the region between the control grid and the anode or target electrodes. Furthermore, it will be appreciated that the control grid is mounted in immediate proximity to the region at which the virtual cathode is established so that highly sensitive control of the transmitted current and high transconductances are obtained. Moreover, because of the constraint of the electrons to parallel flow in the region between the electrodes 19 and 20, stable operation of the device is achieved.

Although the control electrode has been described as comprising a grid or reticulated portion 22, it may very advantageously consist of the wire frame 21. In such case, as in the construction described hereinabove, when the electrode 21 is at a negative potential all of the electrons projected from the aperture in the electrode 19 will be reflected. However, when the electrode 21 becomes positive, the transmitted electrons are highly concentrated and focused to pass through the aperture bounded by the wire frame electrode 21 so that the current to this electrode is extremely small.

Although in the particular embodiment shown and described the current transmitted through the control electrode flows directly to the target electrode 11, the invention may be embodied also in devices wherein the transmitted current is acted upon in various ways between the control and target electrodes. For example, suitable electrodes for velocity varying this current may be provided between the control and target electrodes and appropriate means also provided for extracting energy from the electron stream after it has been velocity varied.

Also, although the invention has been described with particular reference to devices utilizing a sheet-like electron beam and wherein the electrodes are symmetrical with respect to the longitudinal medial plane of the beam, it may be embodied also in devices utilizing a cylindrical beam and wherein the electrodes are axially symmetrical. In this case, the electron gun may be of the construction described in the application Serial No. 319,393, filed February 17, 1940, of John R. Pierce, and the requisite forms for the electrodes 19 and 20 determined by the use of an electrolytic tank as described therein.

It will be understood, of course, that various modifications may be made in the specific embodiment 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 a target electrode, an electron gun for projecting an electron stream toward said target electrode, a control electrode intermediate said electron gun and said target electrode, and means for directing the electrons in said stream along parallel paths throughout a region between said gun and said control electrode and extending to immediately adjacent said control electrode gun, said means including a pair of aligned electrodes one of which is mounted between said gun and said control electrode and the other of which extends outwardly from immediately adjacent said control electrode.

2. Electron discharge apparatus comprising a target electrode, means including a cathode for projecting a stream of electrons toward said target electrode, a control electrode intermediate said means and said target electrode, and means for establishing a region of zero potential immediately adjacent said control electrode, said last means including a pair of centrally apertured electrodes intermediate said cathode and said target electrode and in alignment with said cathode, one of said apertured electrodes being connected electrically to said cathode and extending outwardly from immediately adjacent the periphery of said control electrode and the other of said apertured electrodes being mounted intermediate said cathode and said control electrode

and adapted to be maintained at a positive potential relative to said cathode.

3. Electron discharge apparatus comprising a target electrode, means for projecting an electron stream toward said target electrode including a cathode and an accelerating anode, a control electrode intermediate said means and said target electrode, and means for producing a virtual cathode immediately adjacent said control electrode, said last means including said cathode and a pair of electrodes one of which is mounted adjacent said accelerating electrode and electrically integral therewith and the other of which is mounted immediately adjacent said control electrode and is electrically connected to said cathode.

4. Electron discharge apparatus in accordance with claim 1 wherein said control electrode consists of an electrically conductive frame.

5. Electron discharge apparatus comprising a pair of aligned, centrally apertured electrodes, the opposed surfaces of said electrodes being dished in the same direction, an electron gun opposite one of said electrodes and aligned therewith, a target electrode opposite the other of said electrodes, and a control electrode mounted within the aperture in said other electrode.

6. Electron discharge apparatus in accordance with claim 5 wherein said electron gun comprises a cathode and an accelerating anode and wherein said one electrode is connected electrically to said anode and said other electrode is connected electrically to said cathode.

7. Electron discharge apparatus comprising an electron gun including a cathode and an accelerating electrode in cooperative relation with said cathode, a target electrode spaced from said gun, a control electrode intermediate said electron gun and said target electrode and in alignment with said gun, and means for confining the electrons emanating from said gun to parallel paths throughout a region extending from immediately adjacent said control electrode toward said gun, said means comprising a pair of centrally apertured electrodes in alignment with said gun, one of said apertured electrodes extending outwardly from immediately adjacent said control electrode and being electrically connected to said cathode and the other of said apertured electrodes being mounted intermediate said accelerating and control electrodes.

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