Oct. 17, 1939. H. E. HOLLMANN 2,176,589

ELECTRON BEAM TUBE

Filed Dec. 18, 1936

Fig. 1

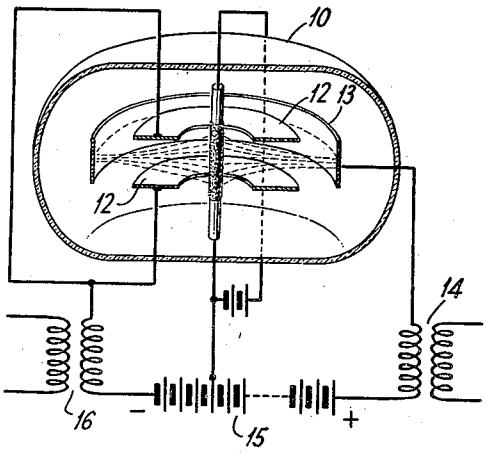


Fig. 2

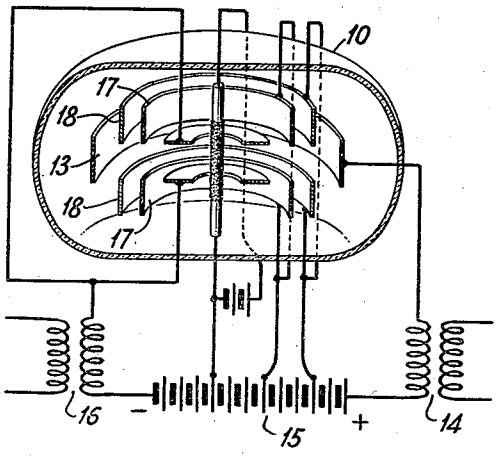
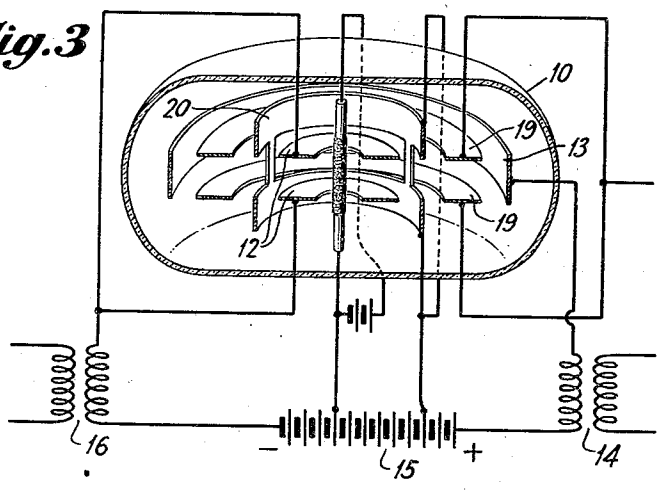


Fig. 3



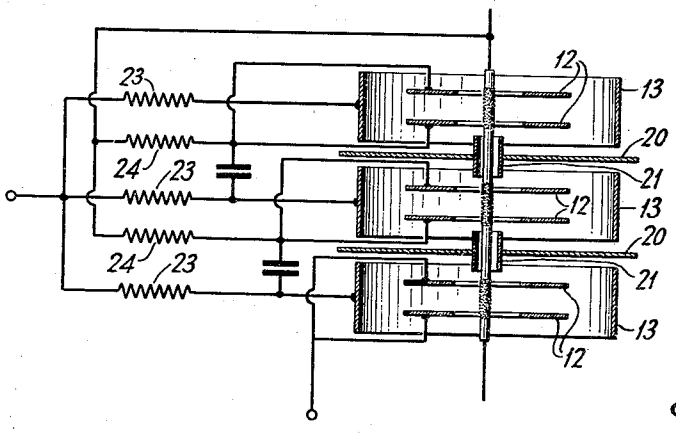


Fig. 4

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ELECTRON BEAM TUBE

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5 Claims. (Cl. 250—152)

The invention relates to a thermionic cathode tube having an electron discharge controlled by an electron lens whereby said discharge has the form of a flat, circular disc with the cathode in the center.

In the cross field tube described in my United States Patent 2,164,922 issued July 4, 1939, there is disclosed a thrmionic discharge tube with a lenticular electron beam substantially concentrated in a plane extending between two annular anodes and deflected at right angles to its median plane by a transversal cross field. The tube operates in accordance with the so-called cross control principle by which, as distinct from the ordinary grid controlled space charge tubes in which the plate current variations are produced by longitudinal intensity control of the discharge, the plate current variations are produced by special displacement of the zone of impingement of the beam on the two anodes. The entire cross field tube has rotational symmetry about the cathode as an axis, the axial thermionic cathode being surrounded in ring fashion by the electrodes of the cylindrical electron lens serving for the production of the lenticular electron beam, by the control electrodes for producing the cross field controlling the beam, and by the two annular anodes. In the center plane of these ring electrodes the electrons flow almost in the form of a flat lenticular disc reduced in size towards the periphery.

For controlling the brilliancy in cathode ray tubes, for instance for television purposes, the principle has been utilized that an electron beam produced by an electron lens may be controlled in intensity by an electron lens without undergoing appreciable deformation of its geometrical form. By this principle the intensity of the cathode ray beam is modulated in accordance with the image currents by means of a striction or Wehnelt cylinder without thereby causing a variation in the velocity or configuration of the beam. Since the striction cylinder does not absorb current and acts solely because of the potential field passed by the electrons, the modulation takes place without requiring energy. If in such a cathode ray tube the cathode ray beam instead of impinging on a fluorescent screen is thrown against a suitable absorption electrode or upon an anode, there is obtained an electron tube in which the current can be controlled in the same manner as by means of a grid without control energy being required. A practical advantage of this type of control as compared with the space charge control hitherto in use is that in this type of control space charge disturbances are entirely absent, and the characteristic of the tube is almost completely linear from zero to the maximum current.

In order that in the electron beam as high amperage as possible may be utilized and to obtain the greatest feasible steepness of the characteristic without increasing the specific current density beyond an allowable degree, the use of a flat beam in place of a fine beam as used in oscillograph and television tubes for the production of a sharp fluorescent spot is preferred and obviously a sharp focusing in the form of a line is not required. However, the irregular field distribution in such a flat beam and in the corresponding electron lens system, especially at the edges, entails border disturbances in the beam and irregularities in the characteristic of the tube, especially in the pronounced regions of curvature, thereby limiting the practically allowable range of control of the tube.

In accordance with the invention, these irregularities are entirely avoided if the electron beam is, as in the case of the cross field tube described in my said copending application given the form of a flat disc extending uniformly in all radial directions from a cathode situated in the center of the disc and is controlled in intensity by electron optical means. Aside from the complete avoidance of border disturbances, a beam discharge of this shape has the great advantage that the entire emission of the axial cathode can be fully utilized, and that the electrons emitted from the cathode in all directions are uniformly accelerated and controlled, and all obey the same electron-optical laws of resolution.

The invention will better be understood by reference to the accompanying drawing in which the figures are vertical sections of forms of disc beam tubes, and in which Figure 1 shows a tube with electron lens control system; Figure 2 a modification utilizing a second electron lens system at fixed potential as a screen; Figure 3 a modification utilizing two electron lens controls separated by an electron lens screen; and Figure 4 a multiple tube in which three electrode systems as shown in Figure 1 are positioned along a common cathode and connected in cascade.

The tube shape obtained from employing the electron-optical current and intensity control in rotational symmetrical disc beam arrangements is in general shown in cross section in Figure 1. The tube comprises the usual highly evacuated bulb 10 enclosing the electrodes, one of which is the axial cathode, which may be a filament, a

helix, or a metal tube coated with electron emitting oxides and indirectly heated by a heater inside it. The electron-optical control and concentration system or electron lens is arranged ring-like about this axis, and in the example shown is in the form of an annular condenser field produced by an annular control electrode combination consisting of two rings 12 concentric with the cathode and constituting electrically a single equipotential control electrode, as the rings are connected so that both are at the same potential, for instance a negative potential. The rings 12 are spaced to leave between them an annular slot in registry with an annular anode 13, which is a sheet metal ring surrounding and concentric with the other electrodes and in position to intercept the electron discharge passing through the annular slot. The electrical field which is produced in the slot or gap between the control rings 12, which form a kind of cylindrical electron lens, effects a concentration of the electron discharge which is emitted from the axial cathode in all radial directions and flows to the annular anode. The anode is connected through a load circuit 14 to a battery 15, which also supplies an input circuit 16 connected to the control electrodes 12.

If a positive potential is applied to the anode 13, and a negative potential to the two control rings or plates 12, a sharply limited disc-shaped or lenticular electron beam, indicated in cross-section by dotted lines, passes to and is focused on the anode. If the annular anode is made fluorescent, for instance by a coating of a fluorescent material on its inner surface, the electron optical concentration and focusing can be clearly seen, as a narrow stripe glows on the entire circumference of the annular anode. If the negative potential of the annular cross field between the control rings 12 is varied with reference to the cathode, the brightness of the fluorescent stripe also varies, showing that the electron density and hence also the plate current correspondingly varies. An optical analogy would be the projection upon a cylindrical surface of a line source of light through an annular cylindrical lens of which the curvature may be varied at will.

If an alternating control potential is applied to the ring control plates 12 and in phase, as distinguished from the cross field according to my said copending application, in which alternating potential of opposite phase on the ring electrodes deflects the beam, the anode current follows changes in the control potential with true amplitude and without distortion. The transgrid action, or extent to which the anode field acts upon the space between the cathode and the electron lens control electrodes 12 can in practice be easily reduced to an unappreciable degree with sufficient spacing of the anode from the cathode, as by placing the anode at the focal distance of the cylindrical electron lens, so that the quality of the tube is greatly superior to the grid tubes with space charge control.

As shown in Figure 2, the transgrid action may also be substantially reduced in case of small tubes if a second shielding electrode combination or electron lens which is maintained at a fixed potential is inserted between the control field and the anode. The shielding cylindrical lens may be two other ring electrodes similar to the control electrodes 12, or a sheet metal plate positioned transversely to the beam and having a slot in the path of the beam; or preferably two pairs of sheet metal rings 17 and 18, the rings in each pair being of the same diameter and concentric with the cathode, with their edges spaced to leave an annular slot, and the pairs of rings having different potentials, as shown, for instance, in Figure 2. The action of these lens systems can be considered as similar to that of a shield or screen grid in a multi-electrode tube with space charge, and as there, the quality of the tube is improved to a remarkable extent by these screen electrodes.

As shown in Figure 3 there may be inserted between the cathode and the original control field another control field by which the average intensity of the electron beam can be affected independently of the control field. This other control field is, as shown in Figure 3, preferably produced by an electrode combination comprising two rings or plate electrodes 19 maintained at the same potential, and it may be shielded against the original control field between the rings 12 by a further screen electrode 20, preferably a tubular sheet metal electrode with an annular slit or aperture. For such a control of the beam amperage and hence also of the steepness of the characteristic practical possibilities of application are seen when the tube operates by means of the plates 12 as a transmitter which can be modulated by means of the second control field electrode 19, or when the degree of amplification of the tube is to be controlled for instance for the purpose of automatic volume control or the like. In this connection there may also be considered the simultaneous amplification of two different frequencies by means of the two electrode combinations or systems 12 and 19.

Finally the principle of the invention may also be readily applied to multiple tubes so made that a long axial cathode common to several electrode systems emits several disc beams in planes parallel to each other. One practical example of construction for multiple tubes is shown in Figure 4. The individual tube stages are for the sake of simplicity shown as made in accordance with the Figure 1, and in the example represented they are connected in series in the manner of a resistance capacity amplifier in cascade. The interspace left between the individual stages to avoid capacitive disturbance coupling may to advantage be protected against the entrance of electrons, preferably by shielding sleeves 21 disposed along the cathode between stages, and the coupling which may be present in spite of these sleeves can be reduced to a minimum by radial metal shields 22 constituting radial disc extensions of the sleeves and extending between stages. The series connection of the tube stages is conventional, including the load resistors 23 and biasing resistors 24. Obviously the individual tubes or stages of this multiple arrangement may also be connected in many other ways and combinations.

I claim:

1. An electron discharge device comprising a rectilinear cathode, a singe annular imperforate anode surrounding said cathode, an annular equipotential control electrode combination interposed between and concentric with said cathode and anode and comprising a pair of parallel flat rings spaced to provide an annular slot extending transversely of said cathode and bisected by the median plane of said anode, said rings being positioned to form the discharge from said cathode to said anode into a lenticular beam, and an electron lens electrode combination interposed between said control electrode combination and

said anode for focusing said lenticular beam on said anode in said median plane, said electron lens electrode combination comprising two annular equipotential lens electrode combinations of different diameters mounted concentric with said cathode and between said control electrode combination and said anode, each of said lens electrode combination having an annular slot aligned with the annular slot in said control electrode combination, the lens electrode nearest the control electrode combination being a tubular sheet metal electrode with walls perpendicular to said median plane of said anode.

2. An electron discharge device comprising a cathode, a single annular imperforate anode surrounding said cathode, an annular equipotential control electrode combination interposed between and concentric with said cathode and anode, said control electrode combination comprising a pair of parallel flat rings extending transversely of said cathode and spaced to provide an annular slot bisected by the median plane of said anode, a tubular sheet metal electrode surrounding said control electrode combination with its wall perpendicular to the median plane of said anode and having an annular slot aligned with said annular slot in said control electrode combination, and an annular equipotential electrode combination surrounding said tubular electrode and having an annular slot aligned with the annular slot in said tubular electrode, said electrode structure being adapted to form the discharge from said cathode to said anode into a lenticular beam focused on said anode.

3. An electron discharge device comprising a rectilinear cathode, a single annular imperforate anode surrounding said cathode, an annular equipotential control electrode combination interposed between and concentric with said cathode and anode and comprising a pair of parallel flat rings spaced to provide an annular slot extending transversely of said cathode and bisected by the median plane of said anode, said rings being positioned to form the discharge from said cathode to said anode into a lenticular beam, and an electron lens electrode combinations interposed between said control electrode combination and said anode for focusing said lenticular beam on said anode in said median plane, said electron lens electrode combinations comprising two sheet metal tubular electrode combinations of different diameters mounted concentric with said cathode and between said control grid and said anode with their walls perpendicular to said median plane of said anode, each of said tubular electrode combinations having at the middle an annular slot aligned with the annular slot of said control electrode and with imperforate portions on each side of said slot extending beyond the planes of said flat rings.

4. An electron discharge device comprising a cathode, a single annular imperforate anode surrounding and coaxial with said cathode, and two annular equipotential electrode combinations of different diameters, each comprising two flat rings of equal diameter spaced to provide an annular slot, said electrode combinations being mounted coaxially with and transversely of said cathode with said annular slots aligned and bisected by the median plane of said anode, and an equipotential tubular sheet metal electrode combination interposed between said annular electrode combinations with its wall perpendicular to said flat rings and having an annular slot in registry with the annular slots in said annular electrode combinations.

5. An electron discharge device comprising an elongated cathode, a plurality of cold electrode assemblies spaced along said cathode to cooperate with separate and distinct portions of said cathode, each of said assemblies comprising an annular anode and an annular equipotential control electrode combination surrounding and coaxial with said cathode and having an annular slot in registry with said annular anode, and metal discs extending radially from said common cathode between said cold electrode assemblies to electrostatically shield each of said assemblies from the others.

HANS ERICH HOLLMANN.