July 23, 1957 W. L. BEAVER 2,800,604

ELECTRON BEAM DISCHARGE DEVICE

Filed Jan. 5, 1954 2 Sheets-Sheet 1

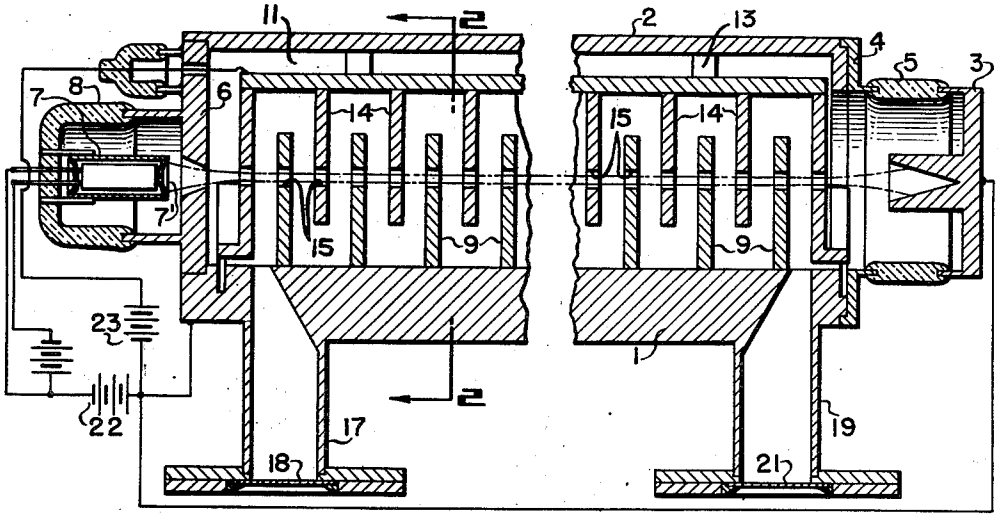


FIG. 1

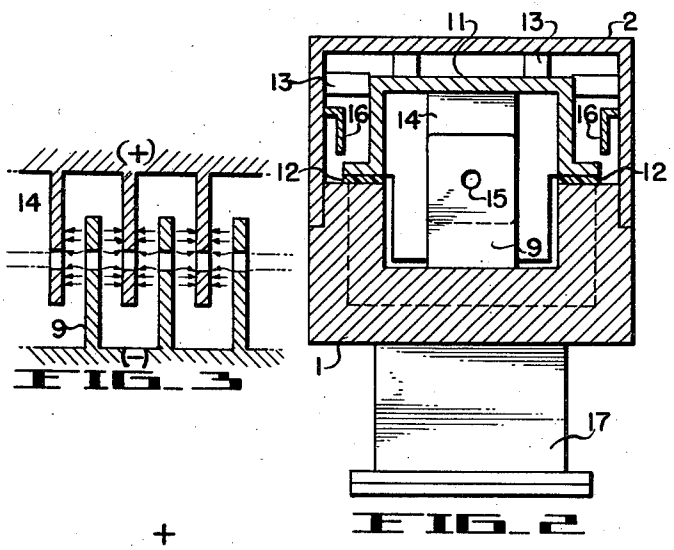


FIG. 3

FIG. 2

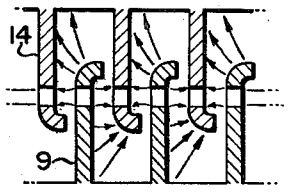


FIG. 5

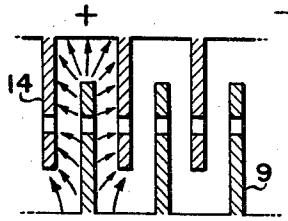


FIG. 4

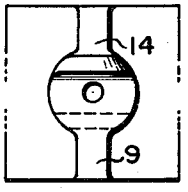


FIG. 6

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July 23, 1957 W. L. BEAVER 2,800,604

ELECTRON BEAM DISCHARGE DEVICE

Filed Jan. 5, 1954 2 Sheets-Sheet 2

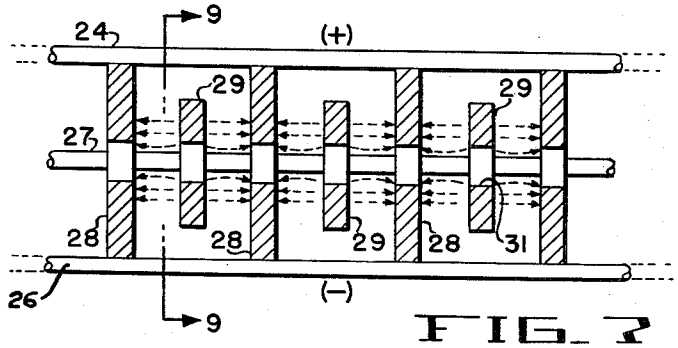


FIG. 7

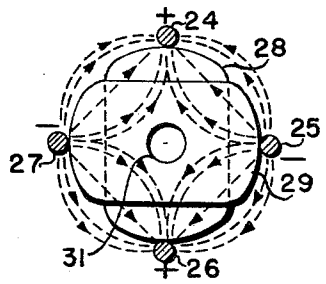


FIG. 8

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ELECTRON BEAM DISCHARGE DEVICE

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Application January 5, 1954, Serial No. 402,272

4 Claims. (Cl. 315—3.5)

This invention relates in general to electron beam discharge apparatus and methods and, more particularly, to novel devices of the slow wave type such as, for example, traveling wave tubes and backward wave oscillators which utilize novel electrostatic focusing methods and apparatus.

One object of the present invention is to provide a novel slow wave structure in which the electron beam passing through the device is electrostatically focused, so that the use of permanent or electromagnets for focusing is unnecessary, or the amount or magnetic field required is substantially reduced.

Another object of the present invention is to provide a novel slow wave structure of the interdigital fin type wherein the electron beam passing therethrough is electrostatically focused and wherein a novel configuration of the interdigital fins is employed to reduce the components of the electrostatic field which are transverse to the direction of the electron beam.

Still another object of the present invention is to provide a novel slow wave structure which comprises a transmission line including a plurality of symmetrically spaced conducting lines and a plurality of loading fins successively positioned along the transmission line, alternate fins being electrically connected to one set of alternately spaced conducting lines while the remaining alternately spaced fins are connected to the remaining set of alternately spaced conducting lines, whereby electric field components transverse to the beam path are substantially eliminated when the two sets of conducting lines are connected to different potentials for electrostatic focusing of the beam.

These and other objects and advantages of the present invention will be more apparent after a perusal of the following specification taken in connection with the accompanying drawings wherein,

Fig. 1 is a longitudinal section view of a traveling wave tube amplifier of the interdigital fin type construction wherein the electron beam passing through the tube is electrostatically focused,

Fig. 2, is a cross-section view of the traveling wave tube amplifier taken along section line 2—2 in Fig. 1,

Fig. 3 is a diagrammatic view showing the idealized electric field lines between successive pairs of the interdigital fins of the traveling wave amplifier device shown in Fig. 1,

Fig. 4 is a view similar to Fig. 3 showing more accurately how the electric field lines may actually occur between the fins of Fig. 1, this view explaining the presence of electric field components transverse to the electron beam path,

Fig. 5 shows a novel interdigital fin construction which may be used in lieu of the fin construction shown in Fig. 1 which substantially eliminates the transverse electric field component in the neighborhood of the electron beam path,

Fig. 6 is an end view of the novel fin construction shown in Fig. 5,

Fig. 7 is a longitudinal section view in diagrammatic form of a novel slow wave tube structure which may be utilized in various ways, such as, for example, in traveling wave tubes and backward wave oscillators, wherein electrostatic focusing of the electron beam passing through the structure may be effectively employed,

Fig. 8 is a cross-section view of the novel slow wave structure of Fig. 7 taken along section line 9—9 in the direction of the arrow.

Referring now to Figs. 1 and 2, there is shown a traveling wave tube amplifier of a type disclosed and claimed in an application of Marvin Chodorow, Serial No. 404,040 filed January 14, 1954, which comprises a main body portion 1 of substantially an elongated U-shape configuration and a top portion 2 also of U-shape cross section which is adapted to fit the main body portion 1 and form the hollow elongated tube body, these bodies being of a good conducting metal such as copper or plated with a good conducting metal. Mounted on the right-hand end of the body is a collector assembly which comprises a metallic electron collector 3, an end adapter 4 and an insulating seal 5 as of glass. Secured on the left-hand end of the tube body is a cathode assembly which comprises the gun anode 6, the cathode gun assembly 7 including the cathode button 7', and the insulating mounting seal 8 as of glass. Secured on the main body portion 1 and extending upwardly within the tube body are a plurality of equally spaced metallic fins or members 9. Mounted within the tube body is a substantially U-shaped elongated member or plate 11, the plate being mounted on the main body 1 and insulated therefrom by insulating spacers 12. The plate 11 is spaced from the wall 2 of the body and electrically insulated therefrom by suitable spacers 13 as of ceramic. Mounted on this plate 11 and extending downwardly within the tube are a plurality of equally spaced fins or members 14, these fins 14 being so arranged as to form a uniform interdigital structure with the fins 9 along the length of the tube. A small aperture 15 is located in each of the fins 9 and 14, these apertures being in axial alignment with the cathode button 7' and the collector 3 so that a clear path is provided for the electron beam from the cathode through the interdigital structure to the collector. A substantially L-shaped member 16 is provided on either side of the tube for utilization as a choke.

An input waveguide 17 having an associated window seal 18 is coupled through an aperture in the body portion 1 to the space between the first set of fins 9 and 14 on the left-hand side in Fig. 1. An output waveguide 19 with its associated window seal 21 is coupled through a second aperture in the main body portion 1 to the space between the furthermost set of fins 9 and 14 on the right-hand side of the tube. The cathode is connected to a source of potential 22 which places the cathode at a negative potential with respect to the main body of the tube and the collector 3. The insulated plate 11 and associated fins 14 are connected to a source of potential 23 which maintains this plate and fin assembly at a positive potential with respect to the main body portion 1 and associated fins 9.

In operation, a stream of electrons, shown in dot-dash lines in Fig. 1, is emitted from the cathode button 7' and is accelerated by the positive voltage on the gun anode, the stream of electrons being focused into a beam while passing through the aperture in the gun anode 6. The beam of electrons proceeds along the path defined by the apertures 15 in the interdigital structure. The expended beam of electrons is then collected by the positively

charged collector electrode 3. The wave energy to be amplified is transmitted into this traveling wave amplifier through the input waveguide 17, the wave energy traveling in a sinuous path along the interdigital structure defined by the fins 9 and 14 such that the wave travels along the tube at the same velocity as the electron beam in a well-known manner and extracts energy from the beam. The amplified wave energy is extracted from this traveling wave tube through the output waveguide 19.

This construction of a slow wave tube is utilized in cooperation with selected electric potentials to electrostatically focus the electron beam so that the beam retains its small cross-section as it proceeds along the length of the tube, thus eliminating the necessity for a magnetic field focusing means such as a permanent magnet or electromagnetic coils. As stated above, the plate 11 and fins 14 are at a potential positive with respect to the main body portion 1 and fins 9 and thus an electric field is produced between the fins 9 and the fins 14 as represented by the arrowed lines. The electric field pattern set up between the interdigital fins which would produce the optimum electron beam focusing is shown in part in Fig. 3. The electric field lines are shown in the direction of electron deflection. In the absence of the apertures, the electric field lines between the fins would be parallel with the axis of the beam and essentially constant across the position of the apertures. With the apertures present, the electric field pattern in the beam path has both longitudinal and circularly symmetric radial components of electric field. The longitudinal component causes the velocity of the electrons in the axial direction to vary. When the electron velocity is smaller than the average, the radial component of electric field produces an inward force, and when the velocity is larger, the radial electric field produces an outward force. Because of the velocity variation, however, the electrons spend more time in the region of inward force and hence acquire a net inward momentum from the focusing field. This can be used to balance the outward momentum due to electron repulsion forces which continually act within the beam, and would cause the beam to diverge if no focusing forces were present.

As a practical matter, however, the electric field lines between the fins in the absence of the apertures form a pattern much like that shown in Fig. 4. Therefore, with the apertures present, the field lines in the immediate vicinity of the beam path do not exert a true radially symmetrical transverse force around the beam. This is because of the unsymmetrical nature of the supporting plates 1 and 11.

As can be seen in Fig. 4, there is a resultant transverse electric field component in a generally upward direction which exerts an upward force on the beam which may, in some instances of use, be undesirable. This force tends to cause the beam to deflect upwardly as it proceeds through the interdigital structure and thus to deviate from the prescribed straight path to a curved path through the tube. This effect can be minimized by making the spacing between the fins 9 and 14 very small compared with their common length. Some correction can also be obtained by increasing the strength of the focusing fields (overfocusing). In important cases, however, these expedients are not desirable or even possible. The transverse deflection effect could also be remedied by bending the traveling wave tube of Fig. 1 slightly in a uniform manner along its length so that the curved beam will be concentric along the curved traveling wave tube. A more practical solution, however, as embodied in this invention is to form the interdigital fins in a suitable manner so that an electric field is produced in the vicinity of the beam path which, when averaged over two adjacent gaps, has no transverse field component strong enough to deflect the electron beam to any appreciable degree. One such novel configuration is shown in Figs. 5 and 6. The free or inner ends of the interdigital fins 9 and 14 have been bent as shown to produce an electric field pattern represented by the arrowed lines, the field in the neighborhood of the beam path averaged over two adjacent gaps being substantially circularly symmetric.

Another novel slow wave structure which may be utilized in electron discharge devices of the type such as traveling wave tubes and backward wave oscillators is shown in Figs. 7 and 8. There is shown in Figs. 7 and 8 only so much of such a novel structure needed to disclose the invention since it will be obvious to one skilled in the art how this structure may be utilized in combination with a gun structure, collector, etc., in such devices as that shown in Fig. 1. This slow wave structure comprises a transmission line including four conducting lines 24 through 27, inclusive, equally spaced radially about a longitudinal axis. A plurality of loading members which are related to the interdigital fins of Fig. 1 are equally spaced along the transmission line, alternate ones 28 of the loading members being mounted between one pair of diametrically opposite conducting lines 24 and 26 while the other alternate loading members 29 are mounted between the remaining pair of diametrically opposite conducting lines 25 and 27. Thus half the loading members are electrically connected to one pair of conducting lines and insulated by air gaps from the other pair while the remaining loading members are electrically connected to the other pair of conducting lines and insulated from the first pair. Axially aligned apertures 31 are located in each of the loading members to form an electron beam path through this slow wave structure. The wave which is to co-act with the electron beam is transmitted through the device around the loading members in a sinuous path.

The electron beam passing down the tube may be magnetically focused in a well known manner or it may be electrostatically focused by operating the two pairs of associated conducting lines at different D. C. potentials. The electric field line components which produce the focusing action are symmetrical about the beam path axis as illustrated by the arrowed lines in Fig. 7 while the electric field line components which are transverse to the beam path in the slow wave structure produce the pattern as shown in dotted lines in Fig. 8. It can be seen from this Fig. 8 that the transverse electric field at the center of the structure is zero and in the neighborhood of the center, that is, the portion that the beam occupies, is very small, and therefore, there is little transverse deflection effect produced on the beam by this transverse electric field.

Since many changes could be made in the above construction of this invention, for example, various shapes and sizes of interdigital members may be employed, and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A slow-wave electron beam device comprising means for producing a beam of electrons directed through said device, a slow-wave structure associated with the beam path comprising an interdigital structure having a first plurality of loading members electrically coupled together and a second plurality of loading members electrically coupled together, said loading members having apertures therein aligned with the beam path, said loading members being interdigitally spaced along the beam path whereby a sinuous wave-energy path is formed through the device defined by the loading members, and means electrically insulating said first plurality of loading members from said second plurality whereby different electrical potentials may be applied to said two pluralities of loading members such that focusing mag-

netic fields extend between adjacent loading members at the beam path apertures, the free ends of each of said loading members being bent toward an adjacent loading member so as to substantially eliminate transverse electric fields in the vicinity of the beam path.

2. In combination with the beam device as claimed in claim 1, a source of electrical potentials, and means for coupling the first and second pluralities of members to said source whereby said first and second pluralities are at different relative potentials.

3. A slow-wave electron beam device comprising means for producing a beam of electrons, a base member having a plurality of equally spaced loading members mounted thereon and extending inwardly into the device, a top plate positioned above the base member having a plurality of equally spaced loading members mounted thereon and extending toward the base member, said latter loading members being in interdigital relationship with said former loading members such that a sinuous wave-energy path is formed through the device by the loading members, said loading members each having an aperture therein, the apertures being aligned within the device so as to be aligned with the

electron beam path therethrough, and means for mounting said top plate on said base member including insulation electrically insulating the top plate from the base member whereby different electrical potentials may be applied to said base and top plate such that focusing magnetic fields extend between adjacent loading members at the beam path apertures, the free ends of said loading members of the two pluralities being bent toward an adjacent loading member so as to substantially eliminate transverse electric fields in the vicinity of the beam path.

4. In combination with the beam device as claimed in claim 3, a source of electrical potentials and means coupling said base member and top plate with said source whereby said base member is at a different potential with respect to said top plate.

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