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ELECTRON GUN

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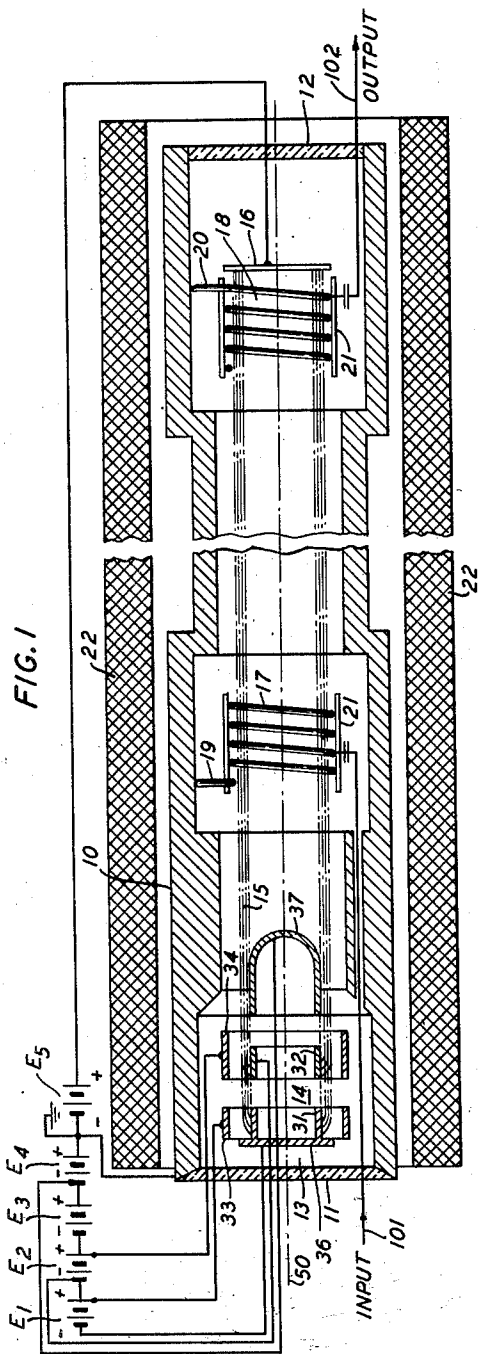


FIG. 2

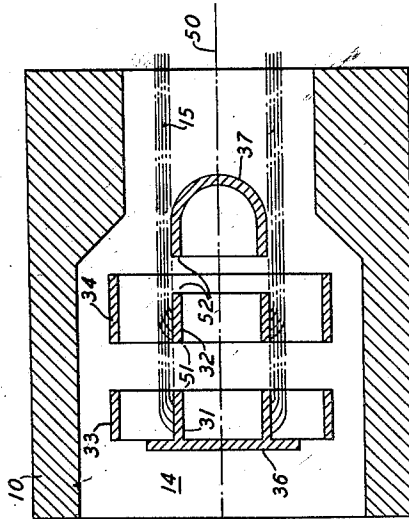


FIG. 3

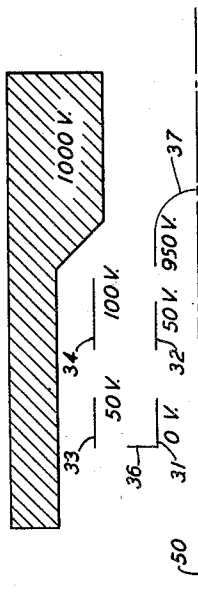


FIG. 4

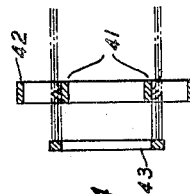
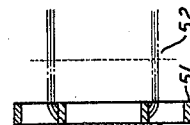


FIG. 5



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ELECTRON GUN

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19 Claims. (Cl. 315—1)

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This invention relates to electron guns and more particularly to electron guns for producing a plurality of electron streams, such as are adaptable for use in amplifying devices of the type known as double stream amplifiers.

In double stream amplifiers, there is utilized an electron flow comprising two streams of electrons having different average velocities. When the currents or charge densities of the two streams are sufficiently large, the streams interact to give an increasing wave. Electromagnetic circuits can be used to impress initially a signal on the electron flow and to derive subsequently an electromagnetic output from the amplified signal present further along the electron flow. An example of an amplifier of this type is disclosed in the application Serial No. 38,928 filed July 15, 1948, of W. B. Hebensreit and J. R. Pierce. In such an amplifier, the amplification takes place in the electron flow itself, and is the result of the interaction therein between the two streams. For such amplification, it is desirable that the two streams intermingle and travel substantially in the same physical space since the gain realized decreases rapidly with any significant separation in space between the two electron streams. In practice, it has been difficult to achieve the desired degree of intermingling. Most of the sources proposed hitherto for double stream flow comprise adjacent emitting areas from which streams of electrons are emitted in the direction of flow desired and proceed side by side, intermingling only at the expense of definition in the two streams.

Accordingly one specific object of this invention is to improve the intermingling of a plurality of electron streams for use in such plural stream tubes.

Another disadvantage in most of the sources proposed hitherto is that the size of the emitting surface has determined the cross-sectional area of the electron stream. As a consequence thereof, the density of the electron stream has been limited by the number of electrons which can be emitted efficiently from a cathode surface of that size. However, in amplifiers where the amplification is related to the density of the electron stream, it may be desirable to provide still higher densities. Accordingly, another object of this invention is to provide efficiently electron streams of increased density.

In general, the object of this invention is to provide a novel electron gun especially adapted for providing a plurality of electron streams.

To this end, the invention provides an electron

gun in which a plurality of cathodes are aligned along a common axis in the direction of the desired electron flow, of which at least one has a surface which emits electrons in a direction transverse to that of the desired electron flow, and which includes means for accelerating the various electron streams in the direction of desired electron flow whereby the various electron streams are made to intermingle and flow either in the same physical space or side by side in a closely spaced relationship.

In accordance with one exemplary embodiment of the invention, the electron gun comprises a plurality of spaced cylindrical cathodes each having a separate control anode and being adapted to serve as the source of a separate electron stream, their radially electron-emissive surfaces being aligned and substantially coextensive with one another in a longitudinal direction transverse to the direction of radial electron emission and in the same direction as the desired longitudinal electron flow, whereby the various electron emissions can be redirected to flow in substantially the same physical space.

In one specific construction of such an embodiment designed for use in a double stream amplifier and which is to be described by way of example as illustrative of the invention, the electron gun comprises two spaced circularly cylindrical cathode members of substantially similar radii, each surrounded by its own control anode member and all members being mounted about a common axis line having the direction of the desired electron flow. By the use of suitable focusing and accelerating means, most of the electron emission from each cathode member is accelerated into a tubular stream coaxial with the common axis line and the various streams are made to coincide substantially in space, whereby a high degree of intermingling is achieved.

The invention will be better understood by reference to the following more detailed description taken in connection with the accompanying drawings forming a part thereof in which:

Fig. 1 is a sectional schematic view of a double stream amplifier having an electron gun constructed in accordance with an exemplary embodiment of this invention;

Fig. 2 shows in cross section an expanded view of the electron gun of Fig. 1;

Fig. 3 is a schematic sketch of this same gun in which typical operating potentials have been shown; and

Figs. 4 and 5 show in cross section alternative embodiments for providing plural stream elec-

tron flow, which can be used in the amplifier of Fig. 1.

With reference more particularly to the drawings, the double stream amplifier shown in Fig. 1 comprises the elongated evacuated envelope 10, which except for the glass end faces 11 and 12 is of a non-magnetic metal. At one end thereof, is a chamber 13 for housing the electron gun structure 14 which produces an electron flow 15 directed towards a collector anode 16 positioned at the opposite end of the tube in target relationship with the gun. The details of the gun structure and the mode of operation for achieving the desired flow are set forth hereinafter. In interacting relationship with the electron flow, there is positioned near the electron gun end, the input wave inducing helix 17 which is shown schematically as being supplied with input signals by way of the lead 101 from an external signal source. The input wave traveling down the helix 17 affects the electron flow in a manner well known in the traveling wave are to impress a signal thereupon. Amplification occurs within the electron flow during further travel along the tube. The amplified wave is derived for utilization purposes by means of the output helix 18, similarly positioned in interacting relationship with the electron flow. The electromagnetic wave induced in the output helix is similarly shown schematically as supplied by means of the lead 102 to external utilization means. Both the input and the output helices are connected to the tube envelope 10 by electrically conducting arms 19 and 20, respectively, thereby imposing the direct-current envelope potential on the helices. The helices are supported in place by the ceramic rods 21, each of which is sprayed on its end nearest the center of the tube with aquadag for terminating purposes. The tube is enclosed in the solenoid 22 which produces an axial magnetic field of uniform intensity B which serves to maintain the definition of the electron flow in its travel through the tube.

The electron gun structure 14 as shown schematically in Figs. 1 and 3 and in cross section in an enlarged view in Fig. 2 comprises two circular cylindrical cathodes 31 and 32 of substantially equal radii and having electron emissive outer surfaces. The two cathodes are aligned and spaced apart by a small gap 51 along the tube axis 50. Concentric about each of the two cathodes is positioned one of two corresponding hollow cylindrical control anodes 33 and 34. The cathodes are heated by conventional heating means which are not shown. Integral with the cathode 31 and at the end thereof further from the cathode 32 is the circular hat or back plate 36 which extends towards but does not reach to the control anode 33. Also aligned with the cathodes 31 and 32, and separated by a small gap 52 from the cathode 32, is mounted the cup-shaped control electrode 37. Beyond the control anode 34 in the direction of electron flow, the tube envelope contracts to decrease the inner diameter of the tube.

To achieve the desired flow, it is important that certain potential relationships be established. First, each cathode must be biased at a potential negative with respect to its corresponding control anode for drawing the emitted electrons away from the cathode. To this end, the direct-current voltage sources E₁ and E₂ are connected between the cathodes 31 and 32 and control anodes 33 and 34, respectively. Additionally

there must be provided an accelerating longitudinal electric field across the gap between the two cathode-anode sets. For this purpose, the control anode 34 and its cathode 32 are made positive with respect to the control anode 33 and its cathode 31, respectively, by connecting the two voltage sources E₁ and E₂ in series adding relationship as shown in Fig. 1.

It is also important to provide additional acceleration in the longitudinal direction so that the electron flow will continue along the tube at a velocity suitable for stream interaction with the electromagnetic wave traveling in the input helix. This additional accelerating field is principally supplied by means of the control electrode 37 and the portion of tube envelope surface which extends the length of the electron path. The collector electrode 16 also provides a local accelerating field in its neighborhood. To obtain longitudinal acceleration, the control electrode 37 is maintained at a potential positive with respect to the control anode 34 by means of the direct-current voltage source E₃ connected therebetween, but at a negative potential with respect to the tube envelope by means of the direct voltage source E₄ connected therebetween. Additionally the collector electrode 16 is kept positive with respect to the tube envelope to minimize secondary emission effects by means of the direct-current voltage source E₅. In the schematic sketch of Fig. 3, some typical operating voltages are shown. These correspond to values for E₁, E₂, E₃ and E₄, of 50 volts, 50 volts, 850 volts and 50 volts, respectively. The lengths of the control anodes 33 and 34 and their axial positions relative to their corresponding cathodes are chosen to produce electric fields across the axial gaps as nearly parallel to the tube axis as possible in the region thereof to be traversed by electrons. Similarly the configuration of the control electrode 37 and its axial position are chosen to contribute to the straightness of the accelerating field across the gap 52.

In operation, the electrons emerge radially from the heated cathodes 31 and 32 under the influence of the voltages on the control anodes 33 and 34, respectively, and then move in orbits about their respective cathode source in the interspace between cathode and anode because of the combined effects of the longitudinal magnetic field set up by the solenoid 22 and the radial electric field existing between each cathode and its control anode. The relevant dimensions, potentials and magnetic field are chosen so that the conditions are those of a conventional magnetron beyond cut-off. As a result, the emitted electrons form in thin tubular sheaths circulating around each cathode and build up a dense space charge that causes some of the electrons to drift longitudinally along the axis of the tube in a direction transverse to their original radial emission direction. The sheath formed around the cathode 31 cannot drift in the direction opposite to that desired for the electron flow because of the intervention of the back plate 36. However, at the end of this cathode adjacent to cathode 32, electrons drift into an accelerating longitudinal field across the gap 51 produced by the potential difference between the two cathode-anode sets. Similarly, electrons from cathode 32 are prevented from travel towards the cathode 31 by the opposing field across the gap 51, but on drifting towards the control electrode 37 enter the large longitudinal accelerating field across the gap 52. The electrons from cathode 31 sim-

ilarly travel past the cathode 32 and enter the main accelerating longitudinal field because of the velocity they acquired in traversing the first gap 51. The radial components of the main accelerating field across the gap between the cathode 32 and the control electrode 37 and the control anode 34 and the tube envelope are preferably kept as small as possible in the region traversed by the electrons. The magnitude of the radial field between the control electrode 37 and the envelope can be varied by varying E_4 . This radial field is reduced to zero, not too abruptly, by the tapering of the control electrode 37.

The electron flow that emerges beyond the control electrode 37 is a tubular stream, of a wall thickness small compared with its mean diameter, and the two electron streams of different average velocities are either completely intermingled and travel in the same physical space or are separated by a small amount within the thin wall of the stream. The source of each of the electron streams is the thin sheath of calculable thickness, surrounding each of the cathodes. The definition of the beam from this source depends upon the overcoming of the effects of radial fields at the accelerating electrodes, including the fields due to space charge in the beam itself. Definition can be increased by increasing the intensity of the magnetic field B.

In particular to minimize the radial field, it has been found desirable, in one construction which has been built, to have the control anode 34 extend longitudinally in the direction of electron flow beyond its cathode 32 and similarly to have the tube envelope contract to a smaller inner diameter beyond the edge of the control electrode 37 as shown in the drawings. With particular sets of accelerating voltages and tube geometry, other refinements of this sort may be advantageous.

It can be appreciated also that other forms and arrangements of control electrodes or control anodes can be successfully employed to provide the necessary accelerating and retarding fields to modify the radial emission direction for longitudinal flow down the tube. For example, a single control anode might be designed to control two or more emitting surfaces.

Also the cylindrical cathodes need not necessarily be circular in cross section, nor all of the same radius, as for example, it may be desirable that the cathode 31 have a larger radius than that of the cathode 32. Moreover, it is not necessary that the emitting surface be smooth, since various filament type cathodes are possible.

Additionally in plural stream tubes, it may be desirable to provide one or more streams by an injection arrangement of the kind described and to utilize other arrangements for providing one or more additional streams. Such other arrangements can, for example, comprise annular emitting surfaces or emitting grids for projecting electron streams into the path of the desired electron flow.

Fig. 4 shows a double stream gun which utilizes the injection arrangement made up of the radially emissive circularly cylindrical cathode 41 and its control anode 42 and the magnetic field provided by suitable flux producing means (not shown) for forming a sheath of electrons around the cathode 41, which is thereafter accelerated in the axial longitudinal direction in the same manner as was described hereinbefore. Additionally, the second stream is provided by the annular cathode 43 which is adapted for emitting

electrons longitudinally along a path that substantially coincides with the stream from cathode 41.

Fig. 5 shows an electron gun which utilizes an emitting grid 52, apertured to pass the electron stream supplied as before by the radially emissive cathode 51 and adapted to project a second stream along substantially the same path.

It can thus be appreciated that the particular arrangement shown is merely illustrative of the principles of the invention. Numerous other arrangements can be devised by one skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. In an electron gun for producing a longitudinal electron flow comprising a plurality of electron streams having different average velocities, a plurality of cathodes aligned and spaced apart along a common axis in the direction of the longitudinal electron flow, each being the primary source of an electron stream and at least one of which has an emitting cylindrical surface which extends in a direction substantially parallel to that of the longitudinal electron flow, and means associated with said surface for forming a sheath of electrons circulating therearound and accelerating this sheath in the direction of electron flow.

2. In an electron gun for producing a longitudinal electron flow comprising a plurality of electron streams having different average velocities, a plurality of cathodes spaced apart along a common axis in the direction of longitudinal electron flow, each serving as the primary source of an electron stream, at least one of said cathodes being cylindrical and having an emission direction transverse to that of the electron flow, and means for confining electrons emitted from said last-mentioned cathode in the emission direction to a sheath circulating therearound and accelerating their travel in the direction of longitudinal electron flow.

3. An electron gun according to claim 2 in which one of said cathodes is an annular emitting surface for projecting an electron stream in the direction of desired electron flow.

4. An electron gun according to claim 2 in which one of said cathodes is a grid positioned in the path of desired electron flow for projecting an electron stream in said direction.

5. In an electron gun for producing a longitudinal electron flow comprising a plurality of electron streams having different average velocities, a cylindrical cathode coaxial with the direction of desired electron flow for emitting electrons in a direction transverse to the direction of electron flow, a control anode surrounding said cathode, means cooperating with said control anode for forming a sheath of electrons in the interspace between said cathode and control anode, a collector anode positioned in target relationship transverse to the direction of electron flow, means for accelerating the electron sheath along a path in the direction of electron flow towards the collector anode, and means for projecting an electron stream of electrons of different average velocity than those comprising the electron sheath in a path in the direction of the collector anode substantially coincident with that of the electron sheath.

6. In an electron gun, a plurality of cylindrical cathodes coaxial with and spaced along a common axis, an anode member associated with each of said cathodes, means cooperating with the anode members for forming an electron sheath about each of said cathodes, and means for di-

recting each of said sheaths along a substantially common path.

7. In an electron gun, a plurality of cylindrical radially emissive cathodes each having a common axis and spaced apart along this axis in the direction of desired electron flow, an anode member surrounding each of said cathodes, means cooperating with said anode member for forming a sheath of electrons about each cathode in the interspace between the cathode and its associated anode member, and voltage supply means for making successive cathodes and anodes along the direction of electron flow more positive for directing each of said sheaths in a substantially common path in the direction of the desired electron flow.

8. In an electron gun, a plurality of cylindrical radially emissive cathodes, each coaxial with and spaced apart along a common axis line in a direction of longitudinal electron flow, a control anode associated with each of said cathodes, means cooperating with said control anodes for forming a sheath of electrons about each cathode in the interspace between each cathode and anode, a collector anode positioned in target relationship across the path of desired electron flow, and means for directing each of said electron sheaths toward the collector anode.

9. In an electron gun, a plurality of circularly cylindrical radially emissive cathodes of substantially similar radii spaced along and coaxial with a common longitudinal axis line, means cooperating with each cathode for forming an electron sheath circulating about each cathode, and means for accelerating the sheaths along substantially coinciding paths in the longitudinal direction.

10. In an electron gun, a plurality of circularly cylindrical radially emissive cathodes of substantially similar radii aligned and spaced along a common axis in the direction of desired electron flow, a control anode associated with each cathode, means cooperating with said control anode for forming an electron sheath about each cathode in the interspace between the cathode and control anode, a collector anode positioned in target relationship transverse to the direction of the desired electron flow, and means for accelerating the electron sheaths toward the collector anode along substantially coincident paths.

11. In an electron gun, a plurality of circularly cylindrical radially emissive cathodes coaxial with and spaced along a common axis line and having their emitting surfaces substantially coextensive in the direction of desired electron flow, means for forming an electron sheath about each of said cathodes, a collector electrode positioned in target relationship transverse to the direction of desired electron flow, and means for accelerating the electron sheaths along substantially coincident paths toward the collector electrode.

12. In an electron gun, a plurality of circularly cylindrical cathodes coaxial with and spaced along a common axis line and having their radially emitting cylindrical surfaces substantially coextensive in the direction of desired electron flow, a separate control anode concentric with each of said cathodes, magnetic means cooperating with each control anode for forming an electron sheath circulating about each of said cathodes, and means for accelerating said sheaths in the direction of desired electron flow along substantially coincident paths.

13. In an electron gun, a plurality of circularly cylindrical cathodes coaxial with and spaced

along a common axis line and having their radially emitting surfaces substantially coextensive in the direction of desired electron flow, a separate control anode concentric with each of said cathodes, magnetic means cooperating with each control anode for forming an electron sheath about each of said cathodes, a collector anode positioned in target relationship transverse to the direction of desired electron flow, and means for accelerating each of the electron sheaths along a substantially common path toward the collector anode.

14. In an electron gun, a plurality of cylindrical cathodes coaxial with and spaced along a common axis, a control anode, means cooperating with the control anode for forming an electron sheath about each of said cathodes, and means for directing each of said sheaths into a substantially common path.

15. In an electron gun, a plurality of cylindrical cathodes coaxial with and spaced along a common axis, a control anode associated with said cathodes, means cooperating with the control anode for forming an electron sheath about each cathode in the interspace between the cathode and control anode, means for accelerating each of said sheaths into a substantially common path, and a collector anode positioned in target relationship transverse to said path.

16. In an electron gun for producing a longitudinal electron flow, a plurality of radially electron-emissive cylindrical surfaces spaced apart along a common longitudinal axis and means for diverting the various radial electron emissions to longitudinal electron flow.

17. In an electron gun for producing longitudinal electron flow, a plurality of radially electron-emissive cylindrical surfaces spaced apart along a common longitudinal axis, means forming a longitudinal magnetic field, and means forming a longitudinal electric field, said magnetic and electric fields coacting to divert the various radial electron emissions to longitudinal electron flow.

18. In an electron gun, a plurality of radially electron-emissive cylindrical surfaces spaced apart and substantially coextensive in a longitudinal direction, means forming a longitudinal magnetic field, and means forming a longitudinal electric field, said magnetic and electric fields coacting to divert the various radial electron emissions into longitudinal electron flow.

19. In an electron gun for producing a longitudinal electron flow, a plurality of radially electron-emissive cylindrical surfaces spaced apart along a common longitudinal axis, and means including voltage supply means for biasing successive surfaces more positive for diverting the various radial emissions to longitudinal electron flow.

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