Aug. 24, 1965 D. A. DUNN ETAL 3,202,863

CROSSED FIELD COLLECTOR

Filed Sept. 19, 1960 3 Sheets-Sheet 1

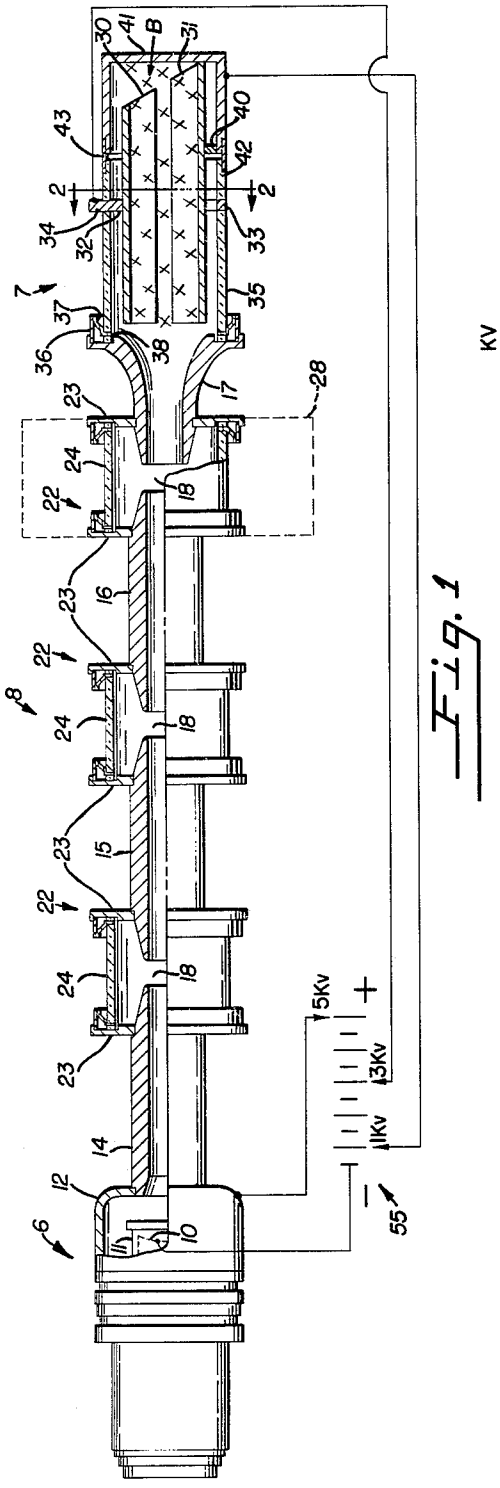


Fig. 1

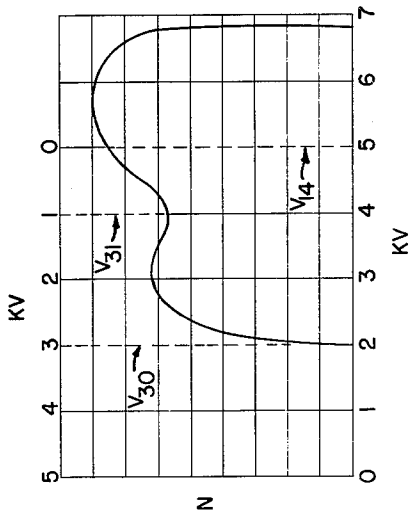


Fig. 3

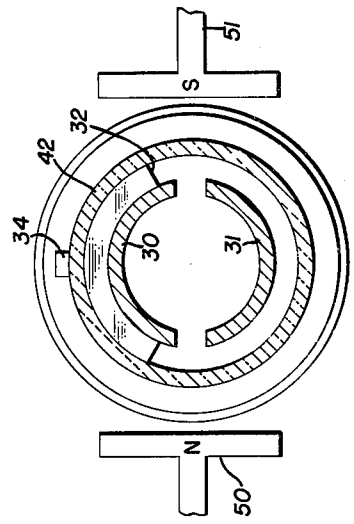


Fig. 2

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CROSSED FIELD COLLECTOR

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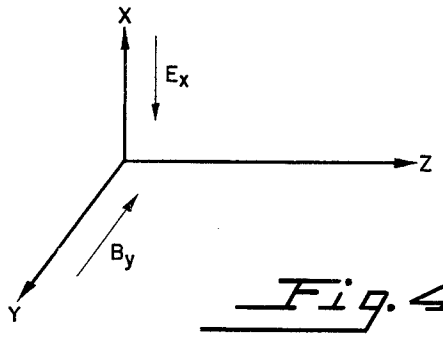


Fig. 4

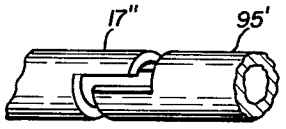


Fig. 10

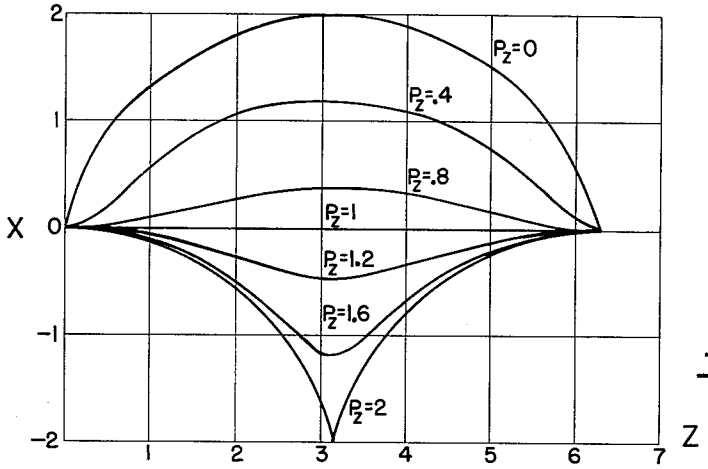


Fig. 5

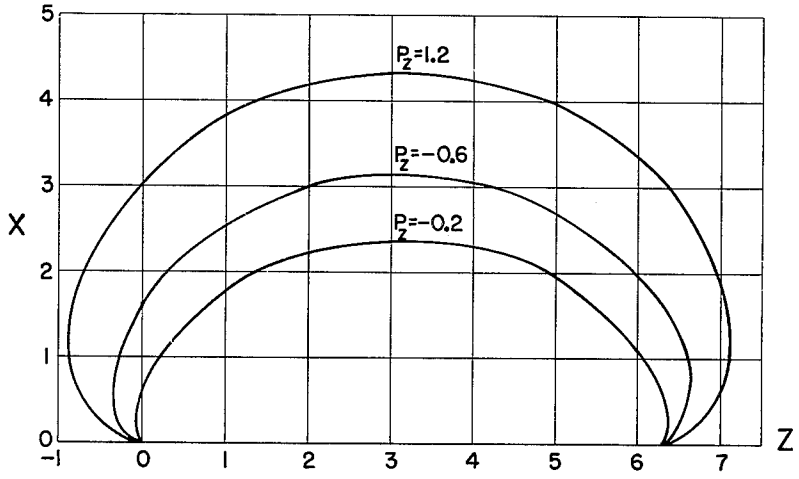


Fig. 6

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Filed Sept. 19, 1960 3 Sheets-Sheet 3

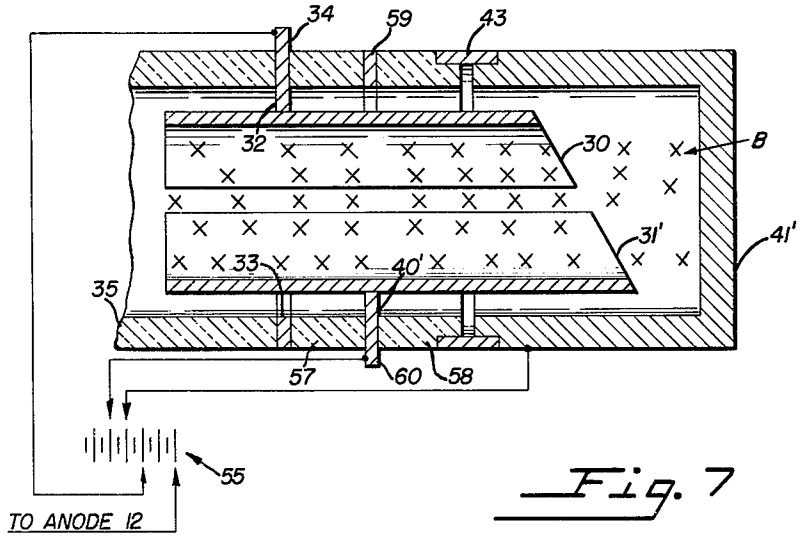


Fig. 7

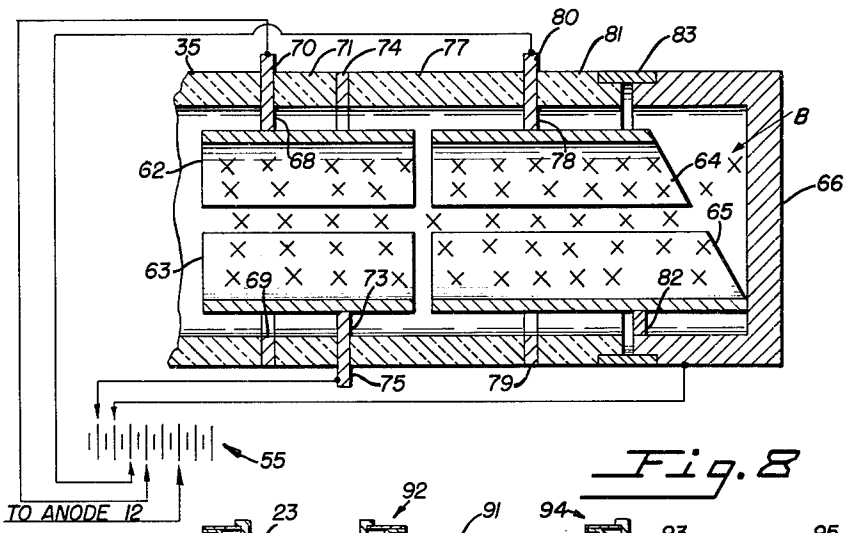


Fig. 8

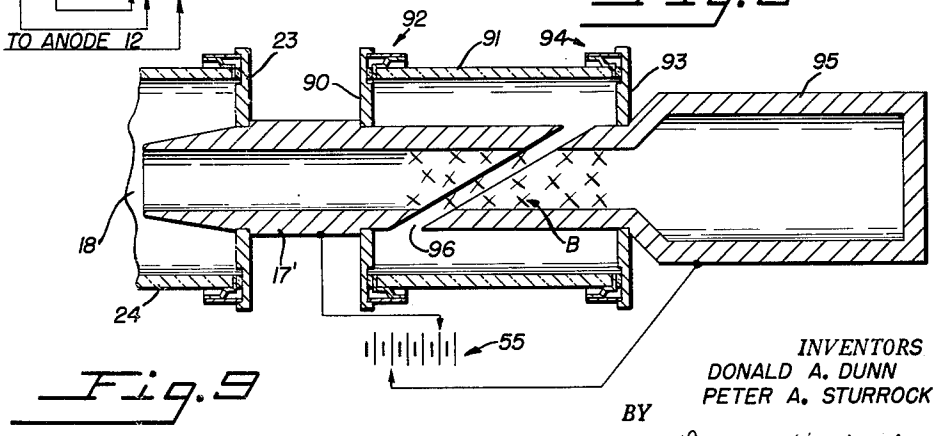


Fig. 9

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CROSSED FIELD COLLECTOR

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Filed Sept. 19, 1960, Ser. No. 56,824
19 Claims. (Cl. 315—5.38)

This invention relates to beam-type electron tubes and more particularly to means for collecting the electron beam of such tubes after the beam has performed its useful function in the tube.

Beam-type tubes in the present state of the art are considered to include klystrons and continuous interaction devices such as traveling wave tubes. Although the invention will be described with particular reference to klystrons, it is applicable to any type of beam tube in which the spent beam contains electrons having a distribution of axial velocities other than a single velocity.

According to conventional practice beam-tube collectors are one-piece devices operated at a high enough potential to collect the slowest electrons in the beam. This of course means that all of the electrons are collected at very high potential and results in tremendous waste of energy.

It has been realized by those skilled in the art that the efficiency of beam tubes could be increased by reducing the collector potential. However, it has also been found that if the collector potential is reduced below the potential necessary to collect the slowest electrons in the spent beam, such slow electrons will in effect be repelled by the collector and will travel back down the beam and disrupt proper operation of the tube. In addition to slow primary electrons which are repelled back down the beam, secondary electrons can escape from a collector and head down the beam with the same disruptive effect. A number of attempts have been made to solve the problem prior to this invention, and while some have constituted an improvement none has been a complete practical solution.

Accordingly, an important object of this invention is to provide an improved collector and method of collecting an electron beam which permits collection of electrons at lower potential than was heretofore possible.

An additional object of the invention is to provide a beam collecting structure and method which will sort according to their velocity and will collect each velocity group at the lowest possible potential.

Another object of the invention is to provide a beam-collecting strucure and method which in addition to collecting primary electrons at reduced potential will also minimize the escape of secondaries from the collector.

Another object of the invention is to provide an improved trap for secondary electrons which can be utilized with a conventional one-piece collector.

A further object of the invention is to provide an improved beam tube having an apparatus which will accomplish the preceding objectives and yet be a practicable structure which is coaxial with the remainder of the tube.

By way of brief description the invention comprises the use of a collector in which there is the combination of a magnetic field and an electric field which cross each other and the beam. The fields are so related in direction that they oppose each other in deflecting primary electrons in the beam and coact in deflecting backward-traveling secondaries. The action of the fields on the primary electrons and the arrangement of the field-forming eletrodes is such that fast electrons are collected on a low-potential electrode and slow electrons are collected on a high-potential electrode.

Other objects, features and advantages of the invention will become apparent from the following specifications and claims when read in connection with the drawings in which:

FIGURE 1 is a side view partly in section showing a klystron embodying a collector according to the invention;

FIGURE 2 is an enlarged cross sectional view on the line 2—2 of FIGURE 1;

FIGURE 3 is a graph showing the velocity spread among the electrons of a spent klystron beam;

FIGURE 4 is a three-dimensional coordinate system used in calculating electron trajectories;

FIGURE 5 is a plot of forward-traveling electron trajectories in a crossed electric and magnetic field;

FIGURE 6 is a plot of backward-traveling electron trajectories in a crossed electric and magnetic field;

FIGURES 7 and 8 are cross sectional views of modified forms of collectors according to the invention;

FIGURE 9 is a cross sectional view of a secondary electron trap according to the invention but used in combination with a conventional one-piece collector; and

FIGURE 10 is a perspective view of a modification of the electron trap of FIGURE 9.

Referring in more detail to the drawings, FIGURE 1 shows a klystron having a beam forming gun 6 at one end, a collection 7 at the other end, and beam interaction means 8 interposed between gun 6 and collector 7.

Electron gun 6 is a conventional structure comprising a cathode 10, focus electrode 11 and anode 12. The beam interaction structure comprises drift tube sections 14, 15, 16 and 17, spaced apart to form three interaction gaps 18. The drift tube sections are connected together by cavity resonator portions 22 formed by circular metal end discs 23 brazed to the drift tube sections and to cylindrical ceramic windows 24.

The structure thus far described is well known in the art as an external cavity klystron; that is, the cavity resonator portions 22 are completed by attaching metal boxes as indicated by the dotted outline 28 around the last or output cavity. In operation a similar metal box is clamped around each of the other two cavities. It will be understood that when the boxes are in place all of the drift tube segments 14–17 are electrically connected and are at the same D.C. potential.

During operation of the klystron, the electron gun 6 forms a beam of electrons which travel through the interaction means 8 and on into collector 7. The cavity resonators interact with the beam in a well known manner so that the first two gaps 18 operate to decelerate some electrons and accelerate others in a manner which causes the electrons in the beam to pass the last or output gap in bunches which drive the output cavity. As a result of this type of modulation the beam as it enters the collector 7 is made up of electrons having a variety of axial velocities. As previously mentioned, it is this difference in electron velocities which causes the need for this invention and makes the invention applicable to any beam-type tube in which the beam to be collected is composed of electrons having differing axial velocities.

Referring now to FIGURES 1 and 2, the collector 7 comprises electrically conductive, electrode segments 30 and 31 on opposite sides of the beam axis. The collector segments are made of non-magnetic material, preferably copper, and are preferably semicylindrical in shape. Electrode 30 is supported on a web portion 32 of a metal ring 33 which has an outwardly extending terminal tab 34. Ring 33 is brazed on one side to a ceramic cylinder 35 which is attached to the drift tube segment 17 by means of a conventional sandwich seal consisting of metal sealing rings 36 and 37 brazed respectively to drift tube 17 and ceramic cylinder 35. The ends of the sealing rings are

welded together. In order to strengthen the seal a ceramic backing ring 38 is brazed to the metal ring 37. This sandwich seal type of joint is also employed to connect ceramic cylinders 24 to the end walls 23 in the resonator portions 22.

Collector segment 31 is supported on a metal web 40 connected to a metal end member 41 and for additional support may be brazed in place where it contacts the end member at the right of FIGURE 1. End member 41 is connected to a ceramic cylinder 42 by means of a relatively thin metal sleeve 43 brazed in place between them. Cylinder 42 is of course brazed to metal ring 33. In large heavy tubes, end member 41 may be connected to cylinder 42 by means of a sandwich type seal previously described at 36–38.

In operation, the klystron thus far described is normally surrounded by a conventional external magnetic circuit (not shown) which develops magnetic field lines running axially through the drift tube sections to prevent the electron beam from spreading. The axial magnetic field is normally terminated by disk-shaped pole pieces surrounding drift tubes 14 and 17. Thus, there is normally no magnetic field in a conventional collector. The invention involves the use of an additional external magnetic circuit for the collector, as shown schematically in FIGURE 2 with north and south poles 50 and 51, respectively. Either a permanent or electromagnetic system may be used. The pole pieces should extend along the length of the collector of sufficient distance to provide field lines throughout substantially the full length of electrode 31 as indicated by the X's collectively represented by the letter B in FIGURE 1. The critical aspect of the collector magnetic field is the direction of the field in relation to the direction of the electrical field between collector electrodes 30 and 31, as will be hereinafter described in detail.

When the klystron is operated, one or more power supplies are used to provide different potentials on the various parts in the relative arrangement indicated by power supply 55. FIGURE 1 shows a single power supply in order to present a clear concept of the relative potentials on the various parts. However, in actual practice at least two separate power supplies are used because certain of the circuits carry very little current and can employ inexpensive supplies. For example, the tube body carries little current and would employ a separate power supply. As indicated by power supply 55, the cathode 10 is at the lowest potential, and the interaction means 8 (or tube body) is at the highest D.C. potential. The collector electrodes 30 and 31 are at intermediate potentials, with electrode 30 being at a positive potential with respect to electrode 31.

As previously mentioned, the invention is concerned primarily with beam-type tubes in which the spent beam contains electrons having a distribution of axial velocities. The extent of this distribution in electron velocities varies with the different types of beam tubes and the different types of operation for which they are designed. However, the curve shown in FIGURE 3 is representative of the velocity distribution of electrons in the beam cross section as the beam enters the collector of a klystron in conventional type of operation. The letter "N" on the X-axis represents the number of electrons, and the "kv." scale at the bottom of the figure represents the electron velocities in kilovolts, relative to a cathode potential of zero kilovolts. It will be understood that in the first drift tube 14 substantially all of the electrons have been accelerated to a velocity corresponding to the potential on the tube body, i.e. the D.C. potential on the interaction device 8. After the electrons have been velocity modulated in passing through the interaction device they enter the collector with the velocity spread shown in FIGURE 3. The dashed vertical line marked V_{14} represents the body potential; i.e., the beam velocity prior to velocity modulation, or 5 kv. as shown by way of example in FIGURE 1. The curve in FIGURE 3 illustrates that, in passing the interaction gaps 18, some of the electrons have been accelerated to a maximum velocity corresponding to about 6.75 kv. while others have been decelerated, with the slowest electron traveling at a velocity corresponding to about 2 kv.

In order to determine the collector potential required to collect the spent beam it should be understood that if the electrons in the beam have been accelerated by the 5 kv. field between the cathode and the anode 12 (body potential), then electrons leaving drift tube 17 at 5 kv. velocity can be decelerated by a 5 kv. decelerating field and can thus be collected on a zero (or cathode) potential collector. Thus in FIGURE 3 all of the electrons on line V_{14} (body potential) and to the right thereof can be collected at zero potential. However, these electrons do not cause the problem. It is the minimum velocity or 2 kv. electrons which require a high potential collector. The minimum velocity electrons have been decelerated from an initial 5 kv. velocity to a 2 kv. velocity so that in effect they have been accelerated by only a 2 kv. field. Accordingly, they can only be decelerated by a 2 kv. field and therefore the collector potential can only be 2 kv. less than the body potential (drift tube 17). This means that the collector must have a potential of at least 3 kv., and this is the potential on collector electrode 30, as indicated by the dashed line V_{30} in FIGURE 3. The scale at the top of the figure represents the collector potential required to collect electrons traveling at any velocity read on the scale at the bottom of the figure.

Having thus described the collector potential with respect to cathode required for minimum velocity electrons will be collected on a high potential electrode, and will now be described. In general the invention contemplates the use of combined magnetic and electric fields which will deflect the electrons so that fast electrons will be collected on a low potential electrode, slow electrons will be collected on a high potential electrode, and electrons traveling backward toward the drift tube 17 will be trapped. The backward traveling electrons are mainly secondaries which are released when primary electrons strike the collector electrodes.

More specifically, the 2 kv. electric field between the high potential collector electrode 31 and the low potential electrode 30 will tend to deflect in an upward direction all electrons regardless of speed and regardless of direction. The direction of the magnetic field B in the collector is from left to right in FIGURE 2 and downward into the surface of the paper in FIGURE 1 as indicated by the X marks. As will be understood by those skilled in the art, the direction of the magnetic field will exert a downward force on primary electrons traveling from left to right in FIGURE 1 and an upward force on electrons traveling in the reverse direction. It is also well known that the magnetic field exerts a greater force on fast electrons than it does on slow electrons. Thus it will be understood that fast primary electrons will be deflected downwardly and collected on the low potential electrode 31; slow primary electrons will be deflected upwardly and collected on the higher potential electrode 30; some medium velocity primary electrons will experience counterbalancing upward and downward forces and will be collected on end member 41 at the same low potential as electrode 31; and all backward traveling electrons will be influenced by the combined upward forces of the electric and magnetic fields so as to be deflected and collected within the collector instead of traveling back down the beam.

From the preceding description it should be clear that the relative direction of the electric and magnetic fields is critical. It is essential that these fields be so oriented that they act in opposite directions on incoming primary electrons and act in the same direction on backward traveling electrons. It should also be noted that according to a preferred construction the higher potential electrode 30 is shorter than electrode 31 and that the elec-

trodes are tapered on their right ends. This construction is adopted so that electrons which are deflected toward electrode 30 but do not contact it by the time they reach the right end of the electrode will be subjected to less of an upwardly directed electric field while still subject to the downward magnetic field and will therefore be collected on the low potential electrodes 31 or 41. It should be understood that specific voltages have been referred to only by way of example and comparison. Actual voltages will vary considerably with size and kind of tube and type of operation.

A more quantitative understanding of the application of the invention can be obtained from the following analysis of electron trajectories in crossed electric and magnetic fields, neglecting the presence of space charge. The analysis starts with the well known equations of motion, as given, for example, by K. R. Spangenberg, "Vacuum Tubes," McGraw-Hill, New York, pp. 116–121, 1948. The orientation of the fields and the coordinates used are shown in FIGURE 4, wherein the X axis is parallel to the electric field, the Y axis is parallel to the magnetic field, and the Z axis is parallel to the centerline of the collector. The arrowheads on the X, Y and Z axes indicate the direction of electron travel which is considered the positive direction. The electric field is assumed to be only in the x direction and the magnetic field only in the y direction, as indicated by the arrow E_x and B_y, respectively. With e taken as the magnitude of the electronic charge, the equations of motion under these conditions are:

$$m\ddot{x}=eE_x-eB_y\dot{z} \tag{1}$$

$$m\ddot{z}=eB_y\dot{x} \tag{2}$$

With the boundary conditions, at $t=0$, that $z(0)=0$, $\dot{z}(0)=u_{0z}$, $x(0)=0$, and $\dot{x}(0)=u_{0x}$, the solution is:

$$Z=p_x \sin T+(1-p_z)(1-\cos T) \tag{3}$$

$$X=p_x(1-\cos T)+T-(1-p_z) \sin T \tag{4}$$

where η=charge-to-mass ratio of an electron

$$X=\frac{\eta B_y^2 x}{E_x} \tag{5}$$

$$Z=\frac{\eta B_y^2 z}{E_x} \tag{6}$$

$$T=\eta B_y t \tag{7}$$

$$p_x=\frac{u_{0x}}{v_e} \tag{8}$$

$$pz=\frac{u_{0z}}{v_e} \tag{9}$$

$$v_e=\frac{E_x}{B_y}=\text{equilibrium velocity} \tag{10}$$

The solutions of Equations 3 and 4 have been plotted in FIGURES 5 and 6 for two conditions which assist in explaining the operation and application of the invention. It should be understood that the equations have been solved in a normalized system of coordinates and therefore the scales and numbers shown in FIGURES 5 and 6 do not correspond directly to the scales and numbers used in connection with FIGURES 1 and 3. FIGURE 5 is a plot of electron trajectories in a crossed field for primary or forward traveling electrons, assuming zero velocity in the X direction upon entering the field (i.e. $P_x=0$). As shown in FIGURE 5, if an electron enters the field traveling in the Z direction at the right velocity, selected as $P_z=1$, it can continue to travel in the Z direction undisturbed. For other magnitudes of the velocity ($P_z\neq 1$) the trajectories are of the form indicated. Thus a collector electrode such as electrode 31 located at $X=-1$ could collect electrons with velocities of $P_z=1.6$ or 2 and of course any faster electrons, but slower electrons such as the one with $P_z=1.2$ would pass through the region without being collected. Similarly, a collector electrode 30 located at $X=+1$ could collect slow electrons with velocities of $P_z=.4$ or less, but faster electrons such as the one with $P_z=.8$ would pass through the region without being collected. As previously explained in connection with FIGURE 3, the potential selected for electrode 30 should be the potential required to collect the slowest electrons in the beam.

FIGURE 6 is a plot of electron trajectories in a crossed field for backward traveling electrons, assuming zero initial velocity in the X direction. As shown in the figure, if electrons start at some point along the Z axis, shown as Z=0, with velocities in the negative Z direction, they turn immediately upward toward the positive electrode such as collector electrode 30 under the combined influence of the electric and magnetic fields. In moving upward the electrons are continually deflected in a clockwise direction by the magnetic field so that they are turned around and travel in the positive Z direction, eventually being bent down toward the negative electrode. Of course if the positive electrode were placed at $X=1$ all of the electrons having the initial negative Z velocities shown in FIGURE 6 would be collected on the positive electrode before they could turn around and be collected on the negative electrode. As FIGURES 5 and 6 show, a crossed field has a nonreciprocal property because, for electrons with positive Z velocities, the electric and magnetic forces are in opposite directions and tend to balance each other, while for electrons with negative Z velocities these forces add.

Having thus described the principles of the invention, several modified structures embodying these principles will now be described. FIGURE 7 is similar to FIGURE 1 and identical or primed reference numbers are used to designate identical or similar parts, respectively. The difference is that in FIGURE 7 the end member 41' is electrically separated from the lower electrode 31' and is connected to a potential intermediate the potential of electrodes 30 and 31' as indicated on power supply 55. In order to accommodate this change the ceramic cylinder 42 of FIGURE 1 is lengthened and divided into two sections 57 and 58, with a metal ring 59 brazed between them. Ring 59 has a terminal tab 60 and a web 40' which supports electrode 31'. In the arrangement of FIGURE 7, electrons, which travel through electrodes 30 and 31' without being collected on either of them, can then be collected on end member electrode 41' at a lower potential than is the case in FIGURE 1. FIGURE 7 of course requires the transverse magnetic field described in connection with FIGURE 1.

FIGURE 8 shows a modified arrangement similar to FIGURE 1 but embodying two more collector electrodes. FIGURE 8 embodies electrodes 62, 63, 64 and 65 plus an end member 66. Electrode 62 is supported on a metal web 68 integral with a ring 69 which carries a terminal tab 70. Ring 69 is brazed to the ceramic cylinder 35 which is connected to drift tube 17 as in FIGURE 1. A ceramic cylinder 71 is brazed to the other side of ring 69. Electrode 63 is supported on a metal web 73 integral with a ring 74 which carries a terminal tab 75. Ring 74 is brazed between ceramic cylinders 71 and 77. Electrode 64 is supported on a metal web 78 integral with a ring 79 which carries a terminal tab 80. Ring 79 is brazed between ceramic cylinders 77 and 81. Electrode 65 is supported on end member 66 by means of a metal web 82, and for rigidity, electrodes 65 can be brazed to member 66 where they are in contact at the right of the figure. End member 66 is connected to ceramic ring 81 by means of a relatively thin metal ring 83 brazed between them.

FIGURE 8 operates in a manner similar to that described for FIGURE 1 but provides a higher degree of refinement. Thus in FIGURE 1 there will be some electrons which do not have sufficient velocity to be collected on the low potential electrode 31 and yet have sufficient velocity that they could be collected at a lower potential

than is required for electrode 30. The object is to provide a greater number of different electrode potentials in the collector so that each velocity class of electrons will be collected at the lowest possible potential, that is, the fastest group of electrons will be collected at the lowest potential, the second fastest group will be collected at the second lowest potential, the third fastest group will be collected at the third lowest potential, and so on until the slowest group of electrons is collected at the highest potential. FIGURE 1 is the simplest but least refined arrangement in that it has only two collector electrode potentials. FIGURE 7 is the next step with three potentials and FIGURE 8 is a further step with four potentials, as indicated by power supply 55. Obviously, more separate potentials could be obtained by adding additional pairs of electrodes to FIGURE 8 and by electrically separating the end member 66 in FIGURE 8 as was done in FIGURE 7. FIGURE 8 of course requires the transverse magnetic field described for FIGURES 1 and 2. In FIGURE 8 the fastest electrons will be deflected down and collected on electrode 63; the next fastest will not be deflected enough to reach electrode 63 but will be collected on electrode 65 or on end member 66; the next fastest will be deflected up and collected on electrode 64 and the slowest electrons will be deflected up the most and collected on electrode 62.

When more than two collector potentials are used, a different mode of operation can be employed; that is, the effect of the magnetic field can be increased relative to the effect of the electric field to the point where even the slow electrons will be deflected downwardly, with the faster electrons being collected on electrodes 31' and 63 in FIGURES 7 and 8, respectively, and the slower being collected on electrodes 41' and 65 in FIGURES 7 and 8, respectively. The effect of the magnetic field can be increased relative to the effect of the electric field in several ways; for example, the strength of the magnetic field can be increased, the strength of the electric field can be decreased, or the speed of all the electrons in the beam can be increased by use of a higher potential electrode through which the beam must pass just prior to entering the collector.

In order to obtain the full benefits of the invention it is of course necessary to collect the beam at several different potentials. However, the directional discrimination of the crossed magnetic and electric fields is useful in connection with a single potential collector. FIGURE 9 discloses an improved trap for secondary electrons for use in connection with conventional one-piece collectors. The structure of FIGURE 9 includes the klystron of FIGURE 1 and shows the output gap 18 with a modified drift tube section 17'. A metal flange 90 is brazed to drift tube 17, and a ceramic cylinder 91 is brazed to flange 90 by means of a sandwich seal arrangement 92. The other end of cylinder 91 is brazed to a metal flange 93 by means of a sandwich seal arrangement 94. Flange 93 is brazed to the one-piece metal collector 95. The electron trap effect is achieved by the slanted gap 96 between drift tube 17' and collector 95. As indicated by power supply 55, the drift tube 17' is at higher potential than collector 95. Thus there will be an electric field across the slanted gap, which field will have a component in the upward direction in FIGURE 9. The magnetic field represented by the X's designated by the letter B is similar to the field described in connection with FIGURES 1 and 2. In operation, primary electrons traveling from left-to-right in FIGURE 9 are deflected upward by the electric field and downward by the magnetic field. Backward traveling secondaries are similarly deflected upward by the electric field and are also deflected upward by the magnetic field so as to be collected on the drift tube segment 17' before they can pass across the output gap and disturb the operation of the tube.

It should be apparent that the slanted gap 96 can be replaced by upper and lower electrodes, such as 30 and 31' in FIGURE 7. However, the slanted gap arrangement provides a strong, easily cooled, practical structure. Obviously the overlap of one tube by the other could be achieved with other shapes besides the simple slanted gap. For example, the adjacent ends of member 17' and 95 could have been cut so as to form overlapping half cylinders; that is the bottom half of the right end of tube 17' could have been cut away, and similarly, the top half of the left end of member 95 could have been cut way to form the shapes shown by member 17'' and 95'' in FIGURE 10.

Having thus described the invention, what is claimed as new and desired to be secured by Letters Patent is:

1. An electron tube comprising means for forming an electron beam, means for interacting with said beam, and means for collecting the electrons in the beam, arranged along a common straight axis in the order named, said collecting means comprising a plurality of semicylindrical electrically conductive segments for collecting electrons in the beam, said electrically conductive segments being insulated from each other and spaced on opposite sides of said straight axis, and magnetic pole pieces of opposite polarity positioned on opposite sides of the beam axis at the same region along the beam as said conductive segments and spaced around the beam axis substantially 90 degrees with respect to said conductive segments, and an electrically conductive end member on said straight axis and electrically insulated from said conductive segments.

2. An electron tube comprising means for forming an electron beam, means for interacting with said beam, and means for collecting the electrons in the beam, arranged along the tube in the order named, said collecting means comprising a first set of electrically conductive segments for collecting electrons in the beam, said first set of electrically conductive segments being insulated from each other and spaced directly opposite each other on opposite sides of the beam axis, and a second set of electrically conductive segments for collecting electrons in the beam, said second set of electrically conductive segments being insulated from each other and from said first set, said second set of segments being spaced directly opposite each other on opposite sides of the beam axis in line with the first set of segments.

3. Electron tube apparatus comprising means for forming an electron beam, means for interacting with said beam, and means for collecting the electrons in the beam, arranged coaxially along the tube in the order named, said collecting means comprising means for forming an electric field having a component passing across said beam normal to the beam axis, said means for forming an electric field collecting electrons in the beam, and means for forming a magnetic field having a component passing across said beam normal to the beam axis and across said electric field normal to said component of the electric field, the direction of said components of said fields being such that electrons traveling forward along said beam tend to be deflected in opposite directions by the two fields and electrons traveling backward along said beam tend to be deflected in the same direction by each of the fields.

4. An electron tube comprising means for forming an electron beam, means for interacting with said beam, and means for collecting the electrons in the beam, arranged along the tube in the order named, said collecting means comprising two semi-cylindrical electrodes extending along the beam axis on opposite sides thereof, said two semicylindrical electrodes collecting electrons in the beam, insulating means connecting said electrodes together and to said interacting means, and means forming a separate terminal for each of said electrodes.

5. An electron tube as claimed in claim 4 in which one of said electrodes extends beyond the other at the end thereof remote from said beam forming means.

6. An electron tube as claimed in claim 4 in which the end of said collecting means remote from said beam forming means is a metal cup-shaped member surrounding one end of said two electrodes.

7. An electron tube as claimed in claim 4 in which the end of said collecting means remote from said beam forming means is a metal member intersecting the beam axis and electrically insulated from said two electrodes.

8. An electron tube comprising means for forming an electron beam, means for interacting with said beam, and means for collecting the electrons in the beam, arranged along the tube in the order named, said collecting means comprising two semi-cylindrical electrodes extending along the beam axis on opposite sides thereof, insulating means connecting said electrodes together and to said interacting means, means forming a separate terminal for each of said electrodes, one of said electrodes extending beyond the other at the end thereof remote from said beam forming means, and a metal cup-shaped end member surrounding one end of said two electrodes, said cup-shaped member being electrically connected to the longer of said two electrodes and insulated from the shorter of said electrodes.

9. Electron tube apparatus comprising means for forming an electron beam, means for interacting with said beam, and means for collecting the electrons in the beam, arranged along the tube in the order named, said collecting means comprising electrically conductive segments for collecting electrons in the beam, said electrically conductive segments being insulated from each other and spaced on opposite sides of the beam axis, magnetic pole pieces of opposite polarity positioned on opposite sides of the beam axis at the same region along the beam axis as said conductive segments and spaced around the beam axis substantially 90 degrees with respect to said conductive segments, and means supplying a given D.C. potential on one of said conductive segments and a relatively lower D.C. potential on the other of said segments, the direction of said magnetic field being such that it tends to deflect said beam toward the conductive segment having said lower D.C. potential.

10. Electron tube apparatus comprising means for forming an electron beam, means for interacting with said beam, and means for collecting the electrons in the beam, arranged along the tube in the order named, a drift tube interposed between said interaction means and said collector means and insulated from the collector means, said collector means comprising a tubular portion adjacent to and insulated from said drift tube, the adjacent ends of said drift tube and tubular portions being cut at an angle so as to form between them a gap which is slanted with respect to the beam axis, means forming a magnetic field having field lines passing through said gap in a direction substantially normal to the beam axis, and a D.C. power source supplying a given potential to said drift tube and a relatively lower potential to said tubular portion, the direction of the magnetic field being such that the field tends to deflect the beam toward the pointed edge of the slanted end on said tubular portion.

11. Electron tube apparatus comprising means for forming an electron beam, means for interacting with said beam, and means for collecting the electrons in the beam, arranged along the tube in the order named, said collecting means comprising electrically conductive segments for collecting electrons in the beam, said electrically conductive segments being insulated from each other and spaced on opposite sides of the beam axis, an electrically conductive end member intersecting the beam, said end member being insulated from one of said segments and electrically connected to the other of said segments, magnetic pole pieces of opposite polarity positioned on opposite sides of the beam axis at the same region along the beam axis as said conductive segments and spaced around the beam axis substantially 90 degrees with respect to said conductive segments, and means supplying a given D.C. potential on said one conductive segment and a relatively lower D.C. potential on said other of said segments, the direction of said magnetic field being such that it tends to deflect said beam toward the conductive segment having said lower D.C. potential.

12. Electron tube apparatus comprising means for forming an electron beam, means for interacting with said beam, and means for collecting the electrons in the beam, arranged along the tube in the order named, said collecting means comprising electrically conductive segments insulated from each other and spaced on opposite sides of the beam axis, an electrically conductive end member intersecting the beam and insulated from each of said conductive segments, means supplying a given D.C. potential on one of said conductive segments and a relatively lower D.C. potential on said end member and a still lower D.C. potential on the other of said conductive segments, whereby an electric field is formed between said segments, and means forming a magnetic field substantially normal to said electric field and substantially normal to the beam axis, the direction of said magnetic field being such that it tends to deflect said beam toward the conductive segment having said still lower D.C. potential.

13. Electron tube apparatus comprising means for forming an electron beam, means for interacting with said beam, and means for collecting the electrons in the beam, arranged along the tube in the order named, said collecting means comprising a first electrode positioned on one side of the beam axis, a second electrode positioned in line with said first electrode, a third electrode directly across the beam from said second electrode, a fourth electrode directly across the beam from said first electrode, all of said electrodes being insulated from each other, means supplying a given D.C. potential on said fourth electrode, a lower potential on said third electrode, a still lower potential on said second electrode, and a lowest potential on said first electrode, whereby an electric field is formed between said first and fourth electrodes, and means forming a magnetic field intersecting said electric field and the beam substantially normal to both, the direction of said magnetic field being such that it tends to deflect said beam toward said first electrode.

14. Electron tube apparatus comprising means for forming an electron beam, means for interacting with said beam, and means for collecting the electrons in the beam, arranged along the tube in the order named, said collecting means comprising a first electrode positioned on one side of the beam, a second electrode positioned in line with said first electrode, a third electrode directly across the beam from said second electrode, a fourth electrode directly across the beam from said first electrode, all of said electrodes being insulated from each other, means supplying a given D.C. potential on said fourth electrode, a lower potential on said third electrode, a still lower potential on said second electrode, and a lowest potential on said first electrode, whereby an electric field is formed between said first and fourth electrodes, and means forming a magnetic field intersecting said electric field and the beam substantially normal to both, the direction of said magnetic field being such that it tends to deflect said beam toward said first electrode, and the relative strengths of said electric and magnetic fields being such that the slowest electrons in the beam are deflected toward said fourth electrode and the fastest electrons in the beam are deflected toward said first electrode.

15. An electron tube comprising means for forming an electron beam, means for interacting with said beam and means for collecting the electrons in the beam, arranged along the tube in the order named, said collecting means comprising electrically conductive segments, for collecting electrons in the beam, said electrically conductive segments being insulated from each other and spaced directly opposite and parallel to each other on opposite sides of the beam axis, and magnetic pole pieces of opposite