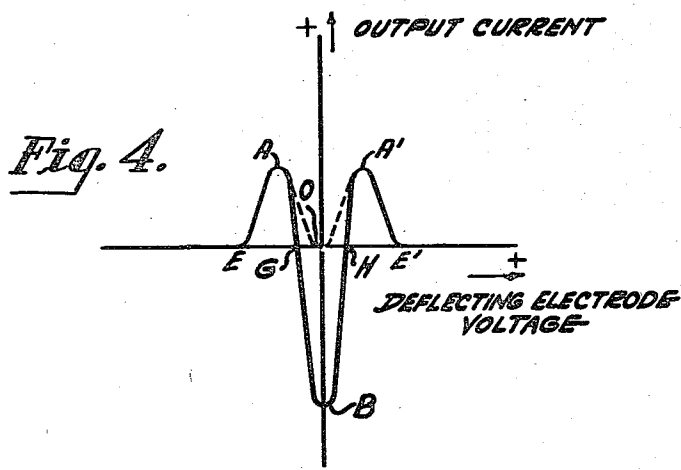
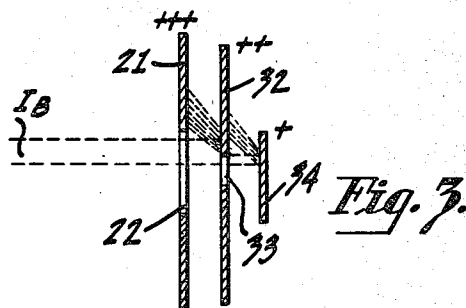
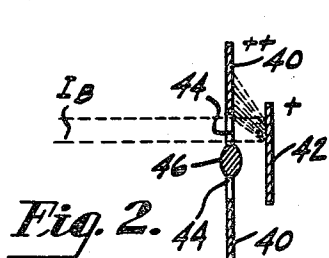
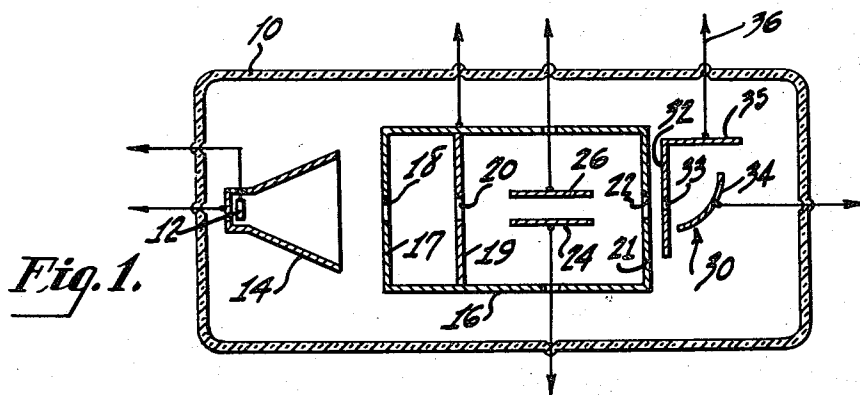


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BEAM DEFLECTION TUBE WITH SECONDARY
EMISSION ELECTRODE
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BEAM DEFLECTION TUBE WITH SECONDARY EMISSION ELECTRODE

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My invention relates to electron discharge devices, and more particularly to an improved type of a beam deflection tube.

One type of electron discharge tube utilizes a well defined electron beam which is moved across a narrow aperture of a shielding anode by a pair of deflecting electrodes. To increase the transconductance of such a tube a dynode or secondary emission multiplier is used as an output anode. The dynode is placed beyond the aperture to intercept the electron beam. The output appears in the dynode to shield-anode circuit.

An object of my invention is to provide an electron discharge device of the beam deflection type having improved electrical characteristics.

More specifically, it is an object of my invention to further increase the transconductance of such tubes.

For this purpose, I have devised a novel arrangement of two secondary emission multipliers which produce an alternating output current of about twice the amplitude for the same deflection voltage.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims, but the invention itself will best be understood by reference to the following description taken in connection with the accompanying drawing, in which:

Fig. 1 is a diagrammatic showing of an electron discharge tube according to my invention;

Fig. 2 is a diagram showing the operation of a conventional beam deflection tube;

Fig. 3 is a diagram showing the operation of a beam deflection tube according to my invention; and

Fig. 4 is a graphic representation of the operating characteristics of a tube according to my invention.

In Fig. 1 is shown a beam deflection tube which can be used as a mixer tube in superheterodyne reception. The beam deflection tube forming the subject matter of my invention is one whose basis of operation is deflection control of an electron beam across an apertured member followed by a secondary emitting target. This tube which embodies my invention includes an envelope 10 having at one end a cathode 12 providing a primary electron beam. A cathode shield 14 surrounds the cathode on the sides and rear to aid in forming the beam. The shield 14 may be operated at a bias or may be connected directly to the cathode. A beam focusing and deflecting electrode assembly 16 is positioned adjacent the cathode and biased at a sufficiently high positive potential to produce a stream of electrons from the

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cathode. The structure of the assembly 16 is designed in the form of a series of apertured barriers or grids, respectively numbered 17, 18 and 21 in Fig. 1, which are used to focus and center the beam. These grid-barriers have, respectively, apertures 19, 20 and 22, which are aligned to center the electron beam and accelerate the beam toward a target assembly 30.

As is shown in Fig. 1, barriers 17, 19 and 21 are constructed in a single assembly in the tube and are also operated at a common positive voltage of preferably around 300 volts. Grids 17 and 19 are designed to form and accelerate the electron beam. Between grid 19 and grid 21 are placed two deflecting plates 24 and 26. These deflecting plates are insulated from the assembly 16 and are used to deflect the electron beam across the opening 22 of grid 21. For example, the local oscillator voltage and the signal voltage may be both applied across the deflection plates or if it is desired the local oscillator voltage may be applied between the assembly 16 and one of the plates, while the signal voltage may be applied between the grid-anode assembly 16 and the other plate. Furthermore, these deflecting plates 24 and 26 may be used to direct the electron beam at any one spot of the target assembly 30 by the application of an appropriate bias between the plates.

In the tube of Fig. 1, I have provided a novel target assembly which gives an increased output current. This target assembly includes an intercepting electrode comprising a plate 32 having an aperture 33 in alignment with the grid apertures 19, 20, and 22. Plate 32 is preferably maintained at around 250 volts positive potential. The surface of plate 32 facing the approaching electron beam is activated to have a secondary emission ratio greater than unity. Thus, plate 32 is a secondary electron emitting electrode or dynode. A dynode in this case may be defined as an electrode having the property of emitting secondary electrons when struck by impinging primary electrons. A conductor lead 36 connected to plate 32 is sealed through the glass envelope wall of the tube for connecting the electrode 32 in an output circuit. The target assembly 30 further includes a target electrode in the form of a curved plate 34 placed directly behind the aperture 33 and preferably maintained at 200 volts positive potential. Plate 34 in this position will receive the impact of the electron beam whenever it passes through the aperture 33. The portion of plate 34 intercepting the arriving electron beam is also activated to have a ratio of secondary electron emission greater than unity.

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Thus, plate 34 comprises a second dynode or emitter electrode.

The first dynode or output electrode 32 is constructed with a beam intercepting portion extending across the beam path and a portion 35 forming a right angle with the electron beam intercepting portion to give the output electrode 32 an L-shaped cross-section. The second dynode 34 preferably has a concave curvature facing the corner of the L-shaped dynode 32. This construction of the two dynodes provides an overlying or covering of plate 34 by the output electrode 32.

The electron beam focused and accelerated by the electrode 16 will pass through the aperture 33 and strike the curved surface of dynode 34. The secondary electron emission released from dynode 34 by this bombardment of the electron beam will be drawn to the more positive output electrode 32. In this manner the first dynode 32 provides a collector for the secondary electron emission from the secondary electron emitter 34.

It is clear from Fig. 1 that the grid plate 21 of the assembly 16 overlies the first dynode surface 32. Furthermore, since plate 21 is maintained at a higher positive potential than the electrode 32, grid portion 21 will act as a collector of the secondary emission released from plate 32 by the bombardment of the impinging electron beam.

The operation of the tube of Fig. 1 is such that the electron emission from cathode 12 will be formed into a beam and accelerated between the deflector plates 24 and 26. The fluctuation of the applied voltages to plates 24 and 26 will cause the electron beam to swing back and forth over aperture 22 onto the intercepting portions of plates 32 and 34. As the beam passes over the aperture 33 it will leave the intercepting surface of the output electrode 32 and will fall upon the secondary emitting surface of the second dynode 34. The aperture 33 is larger than the cross-sectional area of the electron beam so that the beam in passing through aperture 33 is not intercepted by any portion of plate 32. When the beam takes a reciprocating path back and forth over aperture 22 an alternating current will flow in the output circuit of the tube as will be shown below.

Fig. 4 graphically shows the variation of the input current of the tube relative to the changes in the deflecting electrode voltages. If, for example, a proper bias is established between plates 24 and 26, so as to focus the electron beam in a normal path entirely through aperture 33 on to dynode 34, there will be a maximum flow of secondary electrons to electrode 32 from the second dynode 34. This will establish a condition of maximum current flow in one direction in the output circuit. This maximum current flow in the circuit of plate 32 may be represented by point B on the solid curve.

If signal or control voltages are singly or simultaneously applied across plates 24 and 26, the electron beam will sweep back and forth across aperture 33. The output current will be represented by the solid curve on both sides of point B. If the deflections are great enough, the first and second dynodes 32 and 34 will at a certain point simultaneously intercept the electron beam so that the electrons lost by the secondary emission of plate 32 will equal those collected by plate 32 from the primary beam and from the secondary emission of dynode 34. At this point the output current of the tube from plate 32 will become zero. This condition of zero output current is represented by points G and H of the curve. A

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greater deflection of the electron beam, from its normal path through aperture 33, will cause the beam to be entirely intercepted by the secondary emitting surface of the output dynode 32. At this point the secondary emission leaving the electrode 32 will be at a maximum. Also, theoretically, there will be no electron flow to plate 32 except that of the impinging beam. The output current will then be a maximum in the other direction. This is represented by A, A' of the curve of Fig. 4. A still greater deflection of the electron beam will cause the beam to be cut off entirely by the grid barrier 21 so that none of the beam electrons will strike the target assembly 30. The output current obviously drops to zero at this point which is represented by E, E' on the curve of Fig. 4.

Fig. 2 is a sketch of the target of a conventional beam tube as disclosed in Fig. 12 of United States Patent No. 2,294,659 of E. W. Herold. A collector electrode 40 corresponds to plate 21 of Fig. 1. The output electrode 42 is a positive plate corresponding to anode plate 32 of Fig. 1. The collector plate 40 has an aperture 44 for the passage therethrough of an electron beam I_B . The output plate 42 is positioned opposite aperture 44 and its surface upon which electron beam I_B impinges is activated to have secondary emission greater than unity. Positioned in the center of aperture 44 is a post 46 of sufficient width to intercept beam I_B as it is deflected across aperture 44.

As the beam is deflected across the aperture 44, it strikes the output electrode 42 on both sides of the post 46. The current from electrode 42 in the output circuit of the tube of Fig. 2 would be represented by the dotted curve and the upper portions of the solid curve of Fig. 4. The output current would be zero as represented by point E of the curve, where the electron beam I_B falls entirely on collector plate 40. As the beam is swung across the aperture 44, the current in the output circuit increases to a maximum represented by point A of the curve and at which the electron beam I_B falls entirely upon the dynode 42. When the electron beam is entirely intercepted by post 46, the plate current falls to zero as represented at O on the dotted curve. The current rises again to a maximum and then falls to zero as represented by points A' and E', respectively, when the beam swings across the other half of the aperture 44 to the plate 40.

My tube of Fig. 1 provides an alternating output current as illustrated by the solid curve of Fig. 4, while the conventional type tube of Fig. 2, provides an output current which flows only in one direction. The amplitude of output current variation from the median value in my improved tube is much greater than the corresponding amplitude obtained in the conventional tube described. In the conventional tube there is no provision to use the output electrode as a collector of secondary emission from a second dynode.

The efficiency of the tube of my invention will partially depend upon the accuracy with which the electron beam is focused through aperture 33. If the beam does not entirely pass through aperture 33 and if some of the beam simultaneously strikes the secondary emitting surface of plate 32, the maximum current due to the collection of secondary electrons by plate 32 will be lessened.

Furthermore, the efficiency of this tube will also depend upon how effectively the output electrode 32 will collect the secondary emission

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from dynode 34. If there is any escape of secondary electrons around the edges of plate 32 onto the accelerating anode assembly 16, the output current will be decreased by the amount of this electron loss. The design of the collector plate 32 may conceivably be such as to prevent any escape of secondary emission electrons from dynode 34 to parts of the tube other than plate 32. For example, plate 32 may enclose dynode 34 on three sides or entirely on four sides. However, such arrangements will greatly increase the capacitance between electrodes 32 and 34.

Figs. 2 and 3 indicate the output stages of respectively a conventional tube and a tube incorporating my invention. In the conventional type beam deflection tube, such as disclosed in the above mentioned Herold patent, the output stage is as shown in Fig. 2. The output electrode 42 is maintained at a lower positive potential than that of the collector field plate 40. The primary electron beam I_B is caused to impinge on either 40 or 42, or simultaneously upon both. The net output current to target electrode 42 is due to the difference between the primary beam electrons reaching 42 and the secondary electrons leaving 42, and is equal to:

$$I_T = RI_B(d_T - 1) \quad (1)$$

where R is the fraction of the primary beam I_B reaching 42, and d_T is the secondary emission ratio of the surface of 42. Differentiation of (1) with respect to R gives the rate of change of I_T with R :

$$\frac{\Delta I_T}{\Delta R} = I_B(d_T - 1) \quad (2)$$

Thus, a finite deflection of the beam I_B causing a change ΔR in R causes a change in the output current to, or the net loss of electrons from, target 42 equal to $I_B(d_T - 1)$. Equations 1 and 2 apply whether the primary beam impinges in part on plate 40 or post 46.

In Fig. 3, field plate 21, output electrode 32 and auxiliary secondary emitter 34 are maintained at progressively lower beam potentials. The primary electron beam I_B is caused to impinge upon either 32 or 34 or simultaneously upon both. The electron beam I_B thus initiates secondary electron emission from dynode 34 which theoretically is collected by dynode 32. Also, the beam I_B initiates secondary electron emission from electrode plate 32 which in turn is collected by the field plate 21. Under the condition in which the beam I_B falls on plate 32 or plate 34, or simultaneously upon plate 32 and 34, the net output current to output plate 32 is due to the difference between the secondary electrons leaving 32 and the primary electrons and secondary electrons (from 34) reaching 32, and is equal to:

$$I_{T_0} = I_B[R(d_{T_0} - 1) - d_s(1 - R)] \quad (3)$$

where R is the fraction of I_B reaching 32, and d_{T_0} and d_s are the secondary emission ratios of 32 and 34, respectively. Differentiation of (3) with respect to R gives the rate of change of I_{T_0} with R :

$$\frac{\Delta I_{T_0}}{\Delta R} = I_B(d_{T_0} - 1 + d_s) \quad (4)$$

Equations 3 and 4 apply to Fig. 3 when the primary beam is intercepted by 32 or 34, or both. When the beam is intercepted by 21 or 34, or divided between them, Equations 1 and 2, with d_T replaced by d_{T_0} , apply. Equation 4 shows

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that when the beam is divided between 32 and 34, a finite deflection of the beam causing a change ΔR in R causes a change in the output current to electrode 32 equal to $I_B(d_{T_0} - 1 + d_s)$.

If the secondary electron emission ratios d_T , d_{T_0} and d_s are each assumed to be 4, a comparison of Equations 2 and 4 will show that the ratio of I_{T_0} to I_T is $2\frac{1}{3}$. This indicates that for the same change in deflection voltage in both tubes, there is theoretically more than twice the current change or transconductance in the improved tube of Fig. 1. Due to several considerations, however, I have found that the ratio of transconductance between the two tubes compared above is closer to 2.

A comparison of the transconductance of my improved tube with that of the conventional beam deflection tube is also illustrated in Fig. 4. The two curves indicate that for a specific deflection voltage change the output current of the improved tube will change in amount from B to A while in the conventional tube the same deflection voltage change will change the output current only from O to A.

A further study of Fig. 1 and Fig. 4 will show that different results are produced by different biasing or focusing potentials placed upon the deflecting plates 24 and 26. For example, if the electron beam is normally focused entirely through the aperture 33 and if an alternating deflecting potential is imposed between plates 24 and 26, the output current will fluctuate about the point B as discussed above. However, if the electron beam is normally focused so as to fall entirely upon the first dynode 32 and if the beam is deflected by an alternating voltage between plates 24 and 26, the output current will vary on either sides of points A or A', of the solid curve of Fig. 4. Under either of these two conditions with the electron beam focused entirely upon plate 32 or upon plate 34, the output current with no deflection will be a maximum in one direction as shown respectively by points A, A', and B. At these times, it is evident that the transconductance of the tube is zero.

However, it is possible that the beam be focused in a normal path such that part of the beam falls on dynode 32 and the rest of the beam falls on the second dynode 34. In this case the effective plate current will be zero and can be represented by points G or H of Fig. 4 as discussed above. Fig. 4 indicates that under this condition the transconductance of the tube will be at a maximum so that for small deflecting voltages applied between plates 24 and 26 there will be large changes in the plate output current.

While certain specific embodiments have been illustrated and described, it will be understood that various changes and modifications may be made therein without departing from the spirit and scope of the invention.

What I claim as new is:

1. An electron discharge device comprising means for producing and directing a beam of electrons along a normal path, means for deflecting said electron beam away from its normal path, a first and a second dynode spaced along the path of the beam in the order named, each of said dynodes having a portion for intercepting said electron beam, each of said portions having a ratio of secondary electron emission greater than unity, said first dynode having a portion arranged to intercept the secondary emission initiated by the electron beam from said second dy-

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node, means for collecting the secondary emission initiated by the electron beam from said first dynode, and means for connecting said first dynode in an output circuit, whereby a varying output current will be produced in the output circuit.

2. An electron discharge device comprising means for producing and directing a beam of electrons along a normal path, an output electrode and an emitter electrode, said electrodes spaced along the path of said electron beam in the order named, each of said electrodes having a portion for intercepting said electron beam, said intercepting portions of said electrodes being activated to have a secondary electron emission ratio greater than unity, said output electrode forming a collector for the secondary emission from said emitter electrode, means for collecting the secondary emission from said output electrode, and means for deflecting said beam across the intercepting portions of said electrodes.

3. An electron discharge device comprising means for producing and directing a beam of electrons along a path, means for deflecting said electron beam away from said directed path, an emitter electrode having a portion intercepting said electron beam at one portion of said beam, an output electrode having a portion intercepting said electron beam at another portion of said beam, said beam intercepting portions of said electrodes being activated to have a secondary electron emission ratio greater than unity, said output electrode having a second portion positioned to collect the secondary emission from said emitter electrode, and means for collecting the secondary emission from said output electrode.

4. An electron discharge device comprising means including an electron source for producing and normally directing a beam of primary electrons along a beam path, a target assembly for said beam comprising an output electrode adapted to be part of an output circuit and an emitter electrode, said electrodes being spaced along the normal path of said electron beam, said output electrode comprising an apertured intercepting portion positioned between said emitter electrode and said electron source for permitting the undeflected electron beam to pass through the aperture thereof to said emitting electrode and for intercepting at least a portion of said electron beam when the latter is deflected from said normal path, deflection means for moving said beam across the aperture of said intercepting portion of said output electrode, said emitter electrode having an intercepting portion positioned back of said aperture to intercept the portion of said beam passing therethrough, said beam intercepting portions of said electrodes being activated on the side facing the arriving electron beam to have a ratio of secondary electron emission greater than unity, collector means for intercepting the secondary emission from said output electrode, said output electrode forming a collector for the secondary emission from said emitter electrode whereby a varying output current will be produced in said output circuit as the electron beam is deflected across the aperture of said output electrode.

5. An electron discharge device comprising means including an electron source for producing and normally directing a beam of primary electrons along a path, a target assembly for said beam comprising an output electrode adapted to be connected in an output circuit and an emitter electrode, said electrodes spaced along the nor-

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mal path of said electron beam, a portion of said output electrode positioned between said emitter electrode and said electron source for intercepting said beam, means for deflecting said beam away from its normal path over said intercepting portion of said output electrode, said intercepting portion having an aperture positioned in the normal path of said deflected beam, focusing means for directing said electron beam along its normal path through said aperture, said emitter electrode being positioned to intercept said electron beam when directed through said aperture, said electrodes being activated on the beam intercepting portions thereof to have a ratio of secondary electron emission greater than unity, said output electrode overlaying the emitting portion of said emitter electrode for collecting the secondary emission thereof, said beam focusing means including a plate element adjacent the emitting portion of said output electrode for collecting the secondary emission of said output electrode, whereby a varying output current will be produced in the output circuit as the electron beam is deflected from its normal path across the aperture of said output electrode.

6. An electron discharge device comprising means including an electron source for producing and normally directing a beam of primary electrons along a path, a target assembly for said beam comprising an output electrode adapted to be connected in an output circuit and an emitter electrode, said electrodes spaced along the normal path of said electron beam, a portion of said output electrode positioned between said emitter electrode and said electron source for intercepting said beam, means for deflecting said beam away from its normal path over said intercepting portion of said output electrode, said intercepting portion having an aperture positioned in the normal path of said electron beam, focusing means for directing said electron beam along its normal path through said aperture, said emitter electrode being positioned to intercept said electron beam when directed through said aperture, said electrodes each having the surface of the beam intercepting portions thereof activated to have a ratio of secondary electron emission greater than unity, said output electrode having a second portion extending across the activated surface of said emitter electrode for collecting the secondary emission thereof, said beam focusing means including a plate element adjacent the emitting surface of said output electrode for collecting the secondary emission of said output electrode, whereby a varying output current will be produced in the output circuit as the electron beam is deflected from its normal path across the aperture of said output electrode.

7. An electron discharge device comprising means including an electron source for producing and directing a beam of primary electrons along a path, a target assembly for said beam comprising an output electrode adapted to be connected in an output circuit and an emitter electrode, said electrodes spaced along the path of said electron beam, a portion of said output electrode positioned between said emitter electrode and said electron source for intercepting said beam, deflecting means for moving the beam over said intercepting portion, focusing means for directing said electron beam to any point of the intercepting portion of said output electrode, said intercepting portion having an aperture therein, said emitter electrode being positioned to intercept said electron beam when said beam

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is moved across said aperture, said electrodes being activated on the beam intercepting portions thereof to have a ratio of secondary electron emission greater than unity, said output electrode overlaying the emitting portion of said emitting electrodes for collecting the secondary emission thereof, said beam focusing means having an element thereof adjacent the emitting portion of said output electrode for collecting the secondary emission of said output electrodes, whereby an alternating output current will be produced in the output circuit as the electron beam is deflected across the aperture of said output electrode.

8. An electron discharge device comprising means including an electron source for producing a beam of primary electrons, an output electrode including a portion extending transversely of the path of said beam and arranged for intercepting said electron beam, said portion having an aperture, means for focusing said electron beam through said aperture, an emitter electrode spaced behind said output electrode relative to the electron beam direction, said emitter electrode having a portion for intercepting said electron beam passing through said aperture, each of said beam intercepting portions of said electrodes being activated to have a ratio of secondary emission greater than unity, deflecting means for moving said electron beam across the aperture between activated portions of said output electrode, said beam focusing means including a part for collecting the secondary emission of said output electrode, said output electrode forming a collector for the secondary emission from said emitter electrode.

9. An electron discharge device comprising means including an electron source for producing a beam of primary electrons, a target assembly for said beam including an output electrode and an emitter electrode, said electrodes extending transversely of the path of said beam, said output electrode spaced in front of said emitter electrode relative to said electron beam direction and in a position that said output electrode intercepts a portion of said beam and said emitter electrode intercepts the remainder of said beam, deflection means for moving said beam over said target electrodes whereby the amount of current impacting on one electrode is decreased and the amount of beam current impacting the other electrode is simultaneously increased to an equal amount, each of said electrodes being activated on the side facing the arriving electron beam to have a ratio of secondary electron emission greater than unity, said output electrode having a portion for collecting the secondary emission from said emitter electrode when said output electrode has a higher positive potential than said emitter electrode, and said beam producing means including a portion for collecting the secondary emission from said output electrode when said beam producing means is at a higher positive potential than said output electrode.

10. An electron discharge device comprising means including an electron source for producing a beam of primary electrons, an output electrode including a portion extending transversely of the path of said beam to intercept said electron beam, said electrode portion having an aperture, means for focusing said electron beam through said aperture, an emitter electrode spaced behind said output electrode relative to the electron beam direction, said emitter electrode having a portion for intercepting said electron beam

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passing through said aperture, each of said beam intercepting portions of said electrodes being activated to have a ratio of secondary emission greater than unity, deflecting means for moving said electron beam across the aperture between activated portions of said output electrode.

11. An electron discharge device comprising means including an electron source for producing a beam of primary electrons, an output electrode including a portion extending transversely of the path of said beam to intercept said electron beam, said electrode portion having an aperture, means for focusing said electron beam through said aperture, an emitter electrode spaced behind said output electrode relative to the electron beam direction, said emitter electrode having a portion for intercepting said electron beam passing through said aperture, each of said beam intercepting portions of said electrodes being activated to have a ratio of secondary emission greater than unity, deflecting means for moving said electron beam across the aperture between activated portions of said output electrodes, means for collecting the secondary emission of said output electrode, said output electrode forming a collector for the secondary emission from said emitter electrode.

12. An electron discharge device comprising means for producing and directing a beam of electrons along a normal path, means for deflecting said electron beam away from its normally directed path, a target electrode spaced from said beam producing means and extending across said normal beam path, an intercepting electrode having a portion spaced from the normal path of said electron beam for intercepting a portion of said electron beam when deflected from its normal path, a collector electrode having a portion spaced farther from the normal path of the electron beam than said intercepting electrode portion being, said collector electrode portion mounted transverse to the beam path for intercepting a portion of the electron beam when the beam is deflected beyond said intercepting electrode portion, said target and intercepting electrodes being activated to have a secondary electron emission ratio greater than unity.

13. An electron discharge device comprising means for producing and directing a beam of electrons along a normal path, means for deflecting said electron beam away from its normally directed path, a target electrode spaced from said beam producing means and intercepting said normal beam path, an intercepting electrode having a portion with an aperture coaxial with the normal electron path, said portion intercepting a portion of said electron beam when deflected from its normal path, a collector spaced farther from the normal path of said intercepting electrode portion for intercepting a portion of the electron beam when the beam is deflected beyond said intercepting electrode portion, said target and intercepting electrodes being activated to have a secondary electron emission ratio greater than unity.

14. An electron discharge device comprising means including an electron source for producing and normally directing a beam of primary electrons along a beam path, a collector electrode spaced along the beam path and having an aperture encircling the beam path, a first dynode electrode having a portion intercepting the beam path through said collector aperture from said electron source, said dynode portion having an aperture encircling the beam path, a second dy-

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node electrode intercepting said beam path through said first dynode aperture from said electron source, said first and second dynodes being activated to have a secondary emission ratio greater than unity, means for deflecting said electron beam away from the beam path onto said collector electrode, means for connecting said first dynode into an output circuit whereby a varying output current will be produced in the output circuit.

HERBERT NELSON.

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