

June 2, 1942.

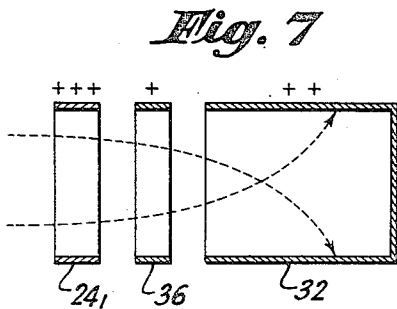
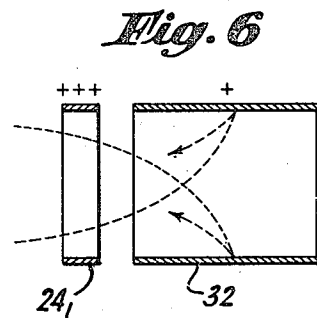
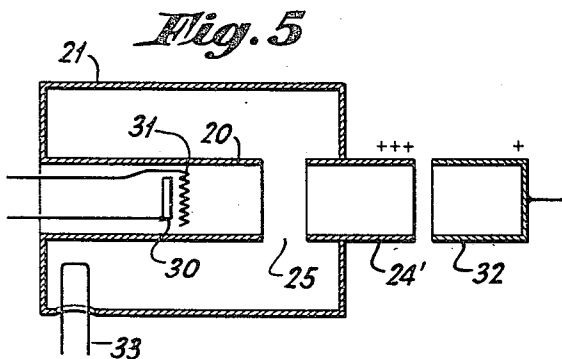
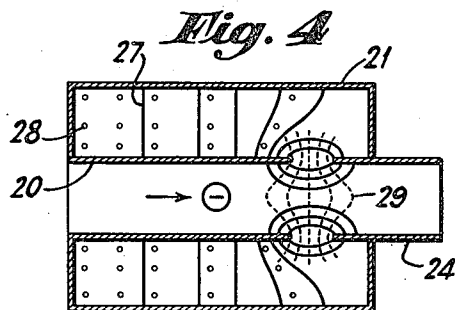
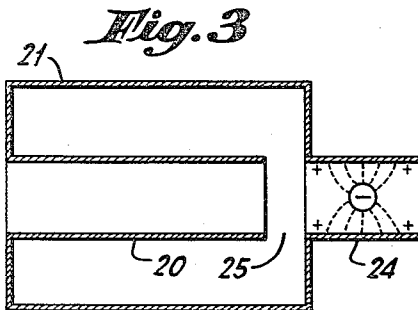
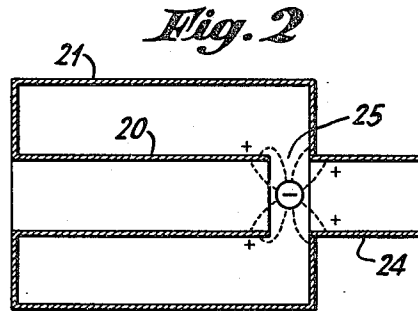
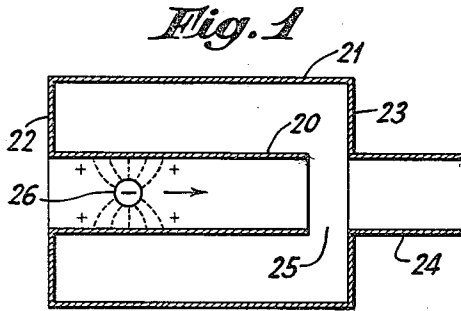
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2,284,733

ELECTRON DISCHARGE DEVICE

Filed Aug. 31, 1939

2 Sheets-Sheet 1



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ELECTRON DISCHARGE DEVICE

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2 Sheets-Sheet 2

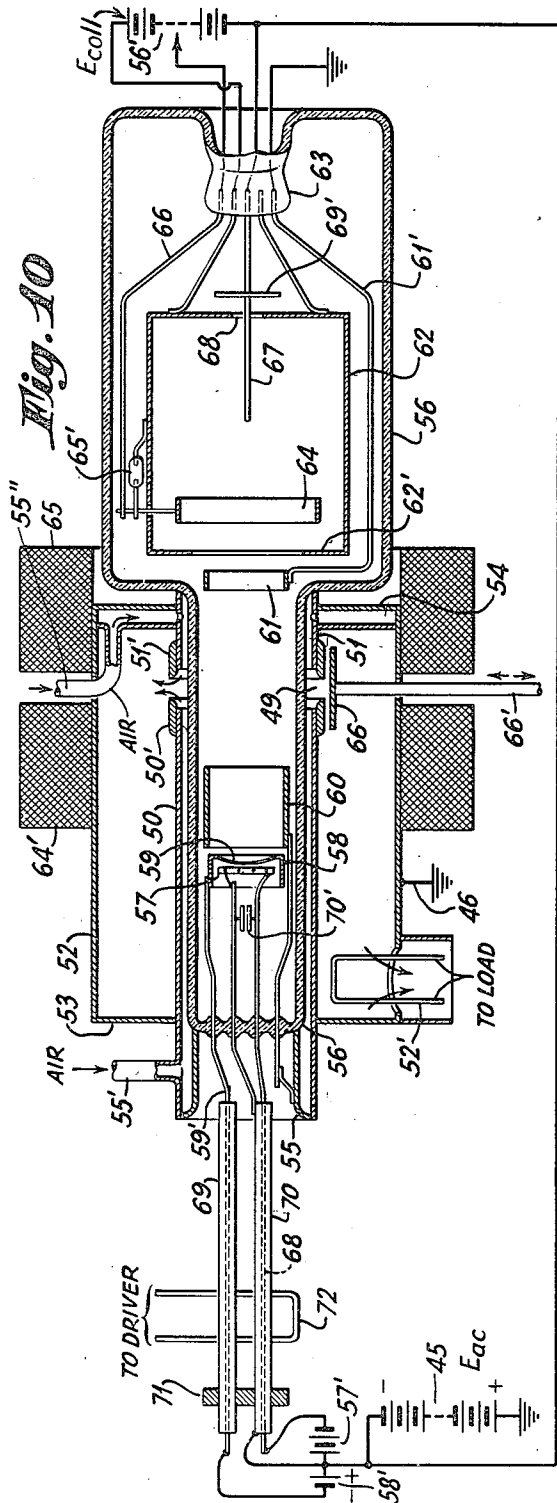


Fig. 9

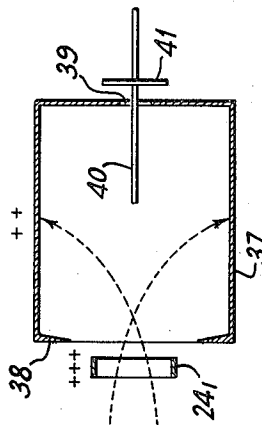
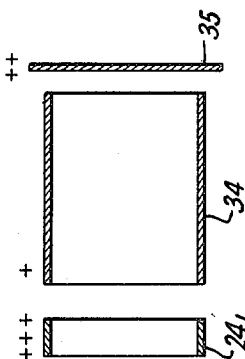


Fig. 8



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2,284,733

ELECTRON DISCHARGE DEVICE

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Application August 31, 1939, Serial No. 292,812

11 Claims. (Cl. 250—27.5)

My invention relates to electron discharge devices, particularly to such devices suitable for use at high frequencies.

It is well known that conventional tubes become inoperative at very high frequencies. The principal difficulties which prevent operation at high frequencies are due chiefly to the following factors, that is, the finite electron transit time producing abnormal loading of the input circuit and loss of trans-conductance of the tube, difficulty in obtaining necessary small coupling between the output electrode and the input electrode which results in regeneration or excessive loading of the output circuit due to the reflected input losses and the consequent loss of power output and efficiency, and increased losses in the circuit due to the presence of large circulating currents at high frequencies and due to an increase in effective resistance of the circuit.

In my copending application, Serial No. 254,239, filed February 2, 1939, and assigned to the same assignee as the present application, I describe and claim an improved electron discharge device particularly suitable for use at high frequencies, and in which electron transit time is not critically related to the period of oscillation, which will function satisfactorily at frequencies at which conventional tubes fail to operate, and in which high frequency losses are minimized, and which is also particularly suitable for use as an amplifier at very high frequencies.

In electron beam tubes of this type designed for high frequency operation and using, for example, accelerating electrodes and a collector, it is advantageous to utilize electrons of high velocity in order to reduce transit time through the active spaces of the tube. This necessitates the use of a high potential on the accelerating electrodes. However, for the purpose of obtaining high efficiency the collector electrode is usually operated at a potential below the potential of the accelerating electrodes, the value of the required collector potential being determined primarily by the high frequency potentials. This condition establishes electric fields near the collector which tend to draw the secondary electrons that may be generated by impact of the primary electrons on the collector from the collector toward the active spaces of the tube. The secondary electrons returning to the active spaces tend to abstract energy from the high frequency circuits and thus reduce the high frequency output power. Furthermore these secondary electrons may be finally absorbed by the

high potential accelerating electrodes, thus increasing the dissipation at the accelerating electrodes and loading the high voltage power supply.

It is therefore the principal object of my invention to provide an improved electron discharge device of the beam type particularly suitable for use at high frequencies and in which secondary emission effects are substantially reduced.

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 drawings in which Figures 1 to 4 inclusive are schematic diagrams illustrating the principles of my invention, Figure 5 is a simplified diagrammatic representation of an electron discharge device of the type under consideration, Figure 6 is a sectional view of the collector electrode illustrating the problem to which applicant's invention is directed, Figures 7, 8 and 9 are sectional diagrammatic representations of the collector electrode construction forming part of applicant's invention for reducing secondary emission effects, and Figure 10 is a longitudinal section of an electron discharge device made according to my invention and its associated circuits and voltage sources.

A better understanding of my present invention can be had by discussing the principles involved in electron discharge devices of the kind under consideration. One such device is described and claimed in my copending application above referred to. Reference is had to Figures 1 to 4 inclusive. In Figure 1 is schematically shown the longitudinal schematic section of a quarter wave concentric line tank circuit comprising an inner tubular conductor 20 which may be cylindrical in cross section, and a hollow outer tubular conductor 21 concentric with the inner conductor 20 and electrically connected to the inner conductor 20 by the conducting plate 22. A second tubular conductor 24 which may be referred to as the aperture extension is coaxial with the conductor 20 and spaced axially from the conductor 20 to provide a gap 25. This tubular conductor 24 and the outer conductor 21 are connected by the conducting plate 23. This arrangement provides a quarter wave concentric tank circuit. If a negatively charged body 26 is projected axially through the inner conductor 20 from left to right, the conditions of the charge distribution on the circuit as the body 26 is

moved along the interior of conductors 20 and 24 is indicated in Figures 1 to 4 inclusive. As shown in the figures, there is a positive charge, equal to the negative charge induced on the inside of the inner conductor near the body. However, initially no charge appears on the outer surface of the inner conductor 20. The induced charge moves with the charged body along the inner surface of conductor 20 until the end of the inner conductor 20 is reached. During the passage of the charged body across the gap 25, the charge is partially imaged on the end of the inner conductor 20 and partially on the outer conductor 24 as shown in Figure 2. The passage of the charged body beyond the gap 25 into the conductor 24 causes the induced charge all to appear on the inner surface of the conductor 24 as shown in Figure 3. The induced charge in transferring from the end of the inner conductor to the conductor 24 flows back over the outer surface of the inner conductor 20 and the inner surface of conductor 21, thus constituting a current flow in the quarter wave tank circuit. If charged bodies are projected past the gap in proper phase and frequency relationship with respect to the resonant frequency of the tank circuit, the circuit may be made to oscillate vigorously merely by the passage of the charged bodies past the gap.

Figure 4 illustrates the configuration of the electric and magnetic fields within the resonant space of the tank circuit when the latter is excited. The solid lines 27 represent the electric field distribution and the circles 28 represent the magnetic lines of force. The dashed lines 29 represent the equipotential surfaces in the gap. Along the major part of the length of the tank circuit the direction of the electric field is substantially radial. However, at the gap 25 the electric field has an axial component. The electric field does not penetrate very far inside the open end of the inner conducting member 20 or inside the conductor 24, but is confined effectively to the space defined approximately by the limiting equipotential lines 29 shown in the figures. The space inside the inner conductor 20 and inside the conductor 24 is essentially field free, therefore no work will be done on a charge moving inside the inner conductor 20 by the electric field until the charge reaches the gap 25. If the charge traverses the gap at the instant when the electric force is in the direction from 20 to 24, the charge will be decelerated, its energy being given up to the tank circuit. A charge crossing the gap during the opposite half cycle when the field is reversed will be accelerated and absorb energy from the circuit. If, however, the number of charges traversing the gap during the first half cycle is greater than during the second, the net effect will be that energy is supplied to the tank circuit.

Thus, the tank circuit may be excited by passing groups of electrons at the proper frequency across the gap between the conductors 20 and 24. The motion of the electrons in the interior of the inner conductor 20 has no effect on the current in the tank circuit. Also high frequency electromagnetic fields which will be generated within the resonant space of the tank circuit penetrate but a short distance inside the conductor 20 and conductor 24 which act as a screen electrode so that the electrons will be influenced by these fields only during their passage across the gap.

In Figure 5 is shown schematically in section

an electrode arrangement of a tube embodying my invention and operating on the principle described above. Mounted within the inner conductor 20 is a conventional cathode 30 and a grid 31, which supply the pulses of electrons in the proper phase relation necessary to excite the tank circuit. A collector electrode 32 may be placed beyond the screening electrode or aperture extension 24'. If now a high potential is applied between the cathode and the tank circuit including electrodes 20 and 24' and also between the collector 32 and cathode 30, a stream of electrons from the cathode will flow toward the collector. If a high frequency voltage is applied between the control grid and the cathode the electron stream will be periodically modulated in intensity. Pulses of electrons traversing the gap 25 will induce high frequency currents between the electrodes 20 and 24'. If the excitation frequency is adjusted to the resonant frequency of the tank circuit a high impedance will exist across the gap 25 at this frequency. The induced currents, therefore, will produce a high radio frequency voltage across the gap 25. The phase of this voltage at or near resonance will be such as to decelerate electrons traversing the gap during the half period of maximum intensity of the electron current in the stream.

The energy lost by the electrons is transformed by the tank circuit into the energy of the electromagnetic field within the resonating space between the inner and outer conductors and then may be conveyed to the useful load by means of a coupling loop such as, for example, 33 extending through an aperture in the outer tubular conductor 21 of the tank circuit.

The high frequency electromagnetic field existing in the resonant space of the tank circuit penetrates only a short distance inside the tubular electrode 20 and inside the tubular screen electrode 24. Therefore, by positioning the control electrode 31 at a suitable distance from the gap 25 the coupling between the input electrodes 30 and 31 and the output electrodes 20 and 24' can be reduced to a negligible value. The collector electrode is also placed at an adequate distance from the gap to minimize coupling between it and the tank circuit. This results in a reduction of the losses caused by the absorption of radio frequency energy from the tank circuit by the collector.

To minimize the transit time effects the electrodes 20 and 24' can be operated at suitable high potentials with respect to the cathode. The adjustment of these potentials is not critical because the functioning of the tube does not depend critically upon the electron transit time. This is because the electrons are effective in exciting the output circuit only during the short period of time that they pass through the field extending through the gap 25. The current collecting electrode 32 can be operated at a much lower potential than the conductors 20 and 24' and in order to obtain a high efficiency it is usually operated at a potential just sufficient to collect all decelerated electrons. To improve the functioning of the device an electrostatic or magnetic focusing of the electron stream can be utilized to prevent electrons from impinging on the high potential electrodes 20 or 24'. Thus these electrodes will not dissipate energy and all of the power generated in the tube will be supplied by the low voltage collector power supply.

In electron discharge devices of the kind un-

der consideration where electrostatic focusing or focusing by means of short magnetic lenses is utilized, the electrons may enter the collector regions at an appreciable angle to the axis and strike the collector near the entrance where there exists an appreciable electric field due to the electrode 24₁ which acts as an accelerating electrode. This tends to accelerate the secondary electrons away from the collector electrode 32 as shown in Figure 6 by the dotted lines. Also, the angular divergence of the entering beam produces an appreciable distribution of electron velocity in the forward direction, thus necessitating higher collecting potentials. In order to suppress secondaries it is necessary to establish a suppressing field near the entrance to the collector electrode.

While the electron beam may be held from diverging by a strong magnetic field and the space charge of the beam itself, which establishes a suppressing field near the surface of the collector thus preventing the escape of secondaries if the automatic space charge suppression is insufficient, the collecting part of the collector may be held at a potential higher than the cylindrical part. As is shown in Figure 8 the cylindrical part 34 is made separate from the collecting part 35. The cylindrical part will then act as a suppressor electrode. However, where it is not desired to use such strong electromagnetic fields and where it is not desired to use a separate part at a high potential, other forms illustrated below can be used.

Figure 7 illustrates the use of a suppressor electrode 36 in the form of a ring in front of the collector 32. In this arrangement the suppressor electrode is maintained at a potential below the collector potential to produce a suppressing field at the collector.

While the arrangement in Figure 7 reduces the number of secondaries a more effective form of my invention is shown in Figure 9. Here the suppressor electrode is in the form of a straight rod 40 positioned along the axis of the collector and extending through an aperture 39 at the rear of the collector 37. By supplying cathode or a slightly positive potential to the rod, a suppressing field is established over the inner surface of the collector. In addition the entrance portion of the collector may be shielded from the accelerating electrode 24₁ by an inwardly extending radial lip 38 which may be made an integral part of the collector 37. The electrons entering the collector are deflected by the suppressor field towards the cylindrical portion of the collector as indicated by the dotted lines. The danger of reflection from low potential regions near the collector is minimized because the deflecting field directs electrons toward more positive regions. With the arrangement shown it has been found possible to reduce secondary electron emission current to 3% of the beam current as compared to 10% if no suppressor is used.

In Figure 10 is shown a tube in longitudinal section embodying a preferred form of my invention. The main body of the tube, which constitutes a quarter wave concentric line output tank circuit includes a pair of tubular coaxial members or electrodes 50 and 51 separated axially by a gap 49 and electrically connected to a concentric outer cylinder or tubular member 52 by means of end plates 53 and 54. These elements form the concentric line output tank circuit. The resonant frequency of the tank circuit may be varied by means of the adjustable condenser

plate 66 movable by insulated rod 66' toward and from the electrodes 50 and 51 to increase or decrease the capacity coupling between these two electrodes. The edges of the electrodes 50 and 51 are thickened and rounded as at 50' and 51' to prevent excessive radio frequency fields at the gap with a consequent dielectric loss in the glass envelope 56 housing the cathode and collector electrodes. To minimize these losses the glass envelope may be provided with a short section near the gap made of low loss dielectric such as special glass, quartz or ceramic. To provide cooling for the tube and particularly to effect adequate cooling of the glass envelope in the region of maximum electric field at the gap a special cooling arrangement can be provided as shown by providing a reentrant portion 55 contacting the glass envelope and forming with the inner tubular members 50 and 51 a hollow tubular casing around the envelope into which air can be forced through tubes 55' and 55'', as indicated. The whole external concentric line tank circuit and the glass envelope can be separated at will.

Envelope 56 which fits within the concentric tank circuit is provided with an indirectly heated cathode 57, control grid 58 having concave shaped grid wires 59 to act also as a focusing electrode to prevent dispersion of the beam through accelerating electrode 60. The control grid can be maintained at either control grid potential or any suitable potential serving to concentrate the electron stream at the start and making it possible to use considerably weaker magnetic focusing fields from solenoids 64' and 65 without undesirable current absorption by the accelerating electrodes 60 and 61 positioned between the cathode and collector electrode 62 supported from the press 63. The reason for using the accelerating electrodes 60 and 61 is to avoid the undesirable effects of charges on the glass wall due to bombardment by stray electrons. The electrodes 60 and 61 are positioned at a suitable distance from the gap 49 between the electrodes 50 and 51 of the output tank circuit so that the radio frequency fields from the space between the tubular members 50 and 52 do not reach them, and thus electrodes 60 and 61 do not form a part of the output circuit and do not carry circulating currents. The electron stream from the cathode 57 modulated and focused by grid 58 traverses the gap between electrodes 50 and 51 and is collected by collector electrode 62.

A parallel wire transmission line comprising tubular conductors 69 and 70 tuned by a conducting bridge 71 form the input circuit. Conductor 59' connected to the focusing electrode and grid 58 extends through tubular member 69 and is connected to the voltage sources 58' to provide the biasing voltage for the electrode 58. The tubular member 70 and the insulated conductor 68 within the tubular member furnish the cathode heating current from the source of voltage supply 57' and the conductor 70 at the same time acts as the cathode lead. Adequate by-passing for high frequency currents is provided by the condenser 70', preferably placed inside the glass envelope and connected between the heater and cathode leads. Radio frequency coupling between the transmission line conductors 69 and 70 and the grid and the focusing electrode is due to the inherent capacity between these conductors and the insulated leads within the hollow conductor tubes. If necessary, additional condensers for capacity coupling can be provided between the conductor tubes and the leads.

When a high potential E_{ac} from voltage source 45 is applied between the cathode 57 and the electrodes 50 and 51 and a voltage E_{con} at 56' between the cathode and collector 62 a stream of electrons from the cathode 57 focused by the magnetic field of the solenoids 64' and 65 is projected toward the collector 62 without impinging on either electrode 50 or 51. If a radio frequency voltage is applied between control grid 58 and cathode 57 by exciting the input circuit by coupling loop 72 connected to a driver the electron stream will be periodically modulated in intensity. Pulses of electrons traversing the gap 49 will induce radio frequency currents in the electrodes 50 and 51. If the excitation frequency is adjusted to the resonance frequency of the output circuit 50, 52 and 51 a high impedance will exist across the gap 49 at this frequency. Consequently, currents induced in electrodes 50 and 51 by electron pulses will produce a high radio frequency voltage across the gap 49. The phase of this voltage at or near resonance will be such as to decelerate electrons passing during the half period of maximum intensity of electron current in the stream. The energy of the decelerated electrons is converted by the tank circuit into energy of the electric and magnetic fields in the resonant space between the inner 50 and outer 52 cylinders and then transferred to the useful load by the coupling loop 52'.

The radio frequency fields penetrate only a short distance inside the tubular electrode 50 and inside the screening electrode 51, a distance effectively less than their diameter so that by positioning the cathode 57, control electrode 58 and the collector 62 at suitable distances from the gap 49, the coupling between the output tank circuit and these last three mentioned electrodes can be made practically negligible. To reduce electron transit time between the control grid 58 and the gap, the electrodes 50 and 51 can be operated at suitably high potentials to increase the speed of the electrons past the gap. However, to obtain high efficiency, the collector electrode potential can be adjusted to a value just sufficient to collect all decelerated electrons and usually has to be only slightly higher than the effective peak radio frequency voltage existing across the gap. The adjustment of the accelerating potential E_{ac} is not at all critical. It is usually adjusted to such a value that the transit time of electrons across the effective length of the gap (smaller than the diameter of the electrode 50) is a fraction of a period so that the loss in transconductance due to transit time is small. With proper design and a sufficient focusing field there is no current to electrodes 50 and 51, so that these electrodes dissipate no energy. The power is supplied only by the collector power supply 56'.

In accordance with my invention, in the form of collector illustrated in Figure 10 the collector 62 is a hollow cup-shaped member provided with an inwardly extending lip or rim 62'. The accelerating electrode 61 is supported from a press by a conductor 61' which also acts as the lead for applying a positive potential to this electrode preferably of the same order as that applied to the electrodes 50, 51 and 52. Insulatingly supported within the collector 62 is a suppressor electrode 64 in the shape of a ring which may be insulatingly supported from the outside of the collector by means of the bead support 65'. Conductor 66 is connected to this suppressor and to a point at a less positive potential than the

collector 62. An axially extending rod 67 extends through an aperture 68 in the rear of the collector and is supported from the press 63, being connected to a point preferably at cathode potential as indicated. A shield 69' carried by rod 67 covers the aperture 68 to prevent electrons from escaping from the interior of the collector 62. A field formation is produced within the collector 62 so that primary electrons are deflected to the sides as indicated by the dotted lines in Figure 9 and the secondary electrons prevented from leaving by the low potential field produced by the electrode 64. In this way substantially all the secondary electrons are prevented from leaving the interior of collector 62 and interfering with the proper operation of the tube. The electrode 64 serves to prevent excessive reflection by the rod which is operated at cathode potential. This particular arrangement of applicant's invention resulted in a reduction of secondary emission current to less than 1.5% of the beam current.

One sample of a tube made according to my invention has an external member 52 of a length of 6" and diameter of 3", the inner tubular members 50 and 51 having a diameter just sufficiently large to permit slipping the concentric line unit over the end of the envelope 56 having an outside diameter of 3/4". The gap between the inner tubular member 50 and 51 was of the order of 1/8".

The dimensions of the improved type of collector electrode in one embodiment of my invention consisted of a cylinder 1 1/2" in diameter and 1 3/4" long; the accelerating electrode 61 is 1/2" in diameter and less than 1/8" wide and the aperture formed by the lip 62' .6" in diameter; the ring suppressor 64 .15" wide had a diameter of 1.1"; suppressor rod 67 extended 3/4" within the collector electrode 62. The materials that are preferably used for the various electrodes are tantalum, carbonized nickel or carbonized nichrome.

The tube was operated under the following conditions: At a frequency of 500 megacycles, power output of 10 watts was obtained, the driving power being about 1 watt and the efficiency about 30%. The accelerating voltage applied to electrode 60 and 61' was of the order of 3000 volts and the collector electrode voltage of the order of 1000 volts. The collector current was approximately 30 milliamperes. The current to the accelerating electrodes was less than 0.5 m. a. when the potential of the suppressor ring was 900 volts and the suppressor rod was held at cathode potential. If the suppressors were maintained at collector potential so that no suppressor action was present the accelerating electrode current rose to 3 m. a. This performance which is readily obtained with a tube made according to my invention contrasts sharply with tubes and circuits of conventional design when an attempt is made to operate them at the higher frequencies.

Thus in a tube made according to my invention electron transit time effects are minimized by utilizing electrons of high velocity. This is accomplished without increasing dissipation and loss in efficiency by separating the functions of the output electrode and current collecting electrode and by making use of electron focusing. The output-input coupling is reduced to a negligible value by screening and separation of the electrodes and circuits. The high frequency losses due to high frequency voltages are mini-

mized by current carrying electrodes of large periphery.

In addition to the above advantages high efficiency results due to collection of the electrons at low velocity and high power output is attained because the collector may be made of adequate size without influencing the performance of the output circuit. A non-regenerative amplification is made possible through the reduction of the output-input coupling to a negligible value. Secondary emission effects are substantially reduced by the use of the arrangements discussed above thus increasing tube and circuit efficiency.

Other uses to which my invention may be put are for example frequency multiplication and generation of oscillations.

While I have indicated the preferred embodiments of my invention of which I am now aware and have also indicated only one specific application for which my invention may be employed, it will be apparent that my invention is by no means limited to the exact forms illustrated or the use indicated, but that many variations may be made in the particular structure used and the purpose for which it is employed without departing from the scope of my invention as set forth in the appended claims.

What I claim as new is:

1. An electron discharge tube including means for projecting a beam of electrons, means for modulating said beam of electrons, an accelerating electrode for said beam of electrons and a collecting electrode for collecting the electrons after their passage past said accelerating electrode, all said means being in said tube in the order named, said collecting electrode comprising an elongated cup-shaped member with its open end in position to receive the beam of electrons, and a ring-like electrode within said cup-shaped member and adjacent the open end thereof for providing a field at a lower potential than that of said collecting electrode.

2. An electron discharge tube including means for projecting a beam of electrons, means for modulating said beam of electrons, an accelerating electrode for said beam of electrons, and a collecting electrode for collecting the electrons after their passage past said accelerating electrode, all said means being in said tube in the order named, said collecting electrode comprising a cup-shaped member with its open end in position to receive the beam of electrons, and electrode means extending along the axis of and within said collecting electrode for establishing a field of lower potential than that of said collecting electrode during operation of said device.

3. An electron discharge tube including means for projecting a beam of electrons, means for modulating said beam of electrons, an accelerating electrode for said beam of electrons, and a collecting electrode for collecting the electrons after their passage past said accelerating electrode, all said means being in said tube in the order named, said collecting electrode comprising a hollow member open at one end with the open end in position to receive the beam of electrons, a ring-like electrode adjacent the open end of said collecting electrode and coaxial with said collecting electrode for providing a field of lower potential than said collecting electrode, and electrode means extending along the axis of and within said collecting electrode for establishing a field of lower potential than that of said col-

lecting electrode during operation of said electron discharge device.

4. An electron discharge tube including a pair of tubular coaxial conducting members separated by a gap, a source of electrons for projecting a beam of electrons past said gap, means for modulating said beam of electrons prior to their passage past said gap, means for accelerating said beam of electrons, and a collecting electrode for collecting the electrons after their passage past said gap, all said means being in said tube in the order named, said collecting electrode comprising a hollow member open at one end with the open end in position to receive the beam of electrons, an inwardly extending radial lip around the open end of said collecting electrode, a ring-like electrode adjacent the open end of said collecting electrode and coaxial with said collecting electrode for providing a field of lower potential than said collecting electrode, and electrode means extending along the axis of and within said collecting electrode for establishing a field of lower potential than that of said collecting electrode during operation of said electron discharge device.

5. An electron discharge tube including a pair of tubular coaxial conducting members separated by a gap, a source of electrons for projecting a beam of electrons past said gap, means for modulating said beam of electrons prior to its passage past said gap, and a collecting electrode for collecting the electrons after their passage past said gap, all said means being in said tube in the order named, said collecting electrode comprising a cup-shaped member with its open end in position to receive the beam of electrons, an inwardly extending radial lip at the open end of said cup-shaped member, a ring-like electrode within the collecting electrode and adjacent said lip for providing a field of lower potential than that of said collecting electrode.

6. An electron discharge tube including means for projecting a beam of electrons, means for modulating said beam of electrons, an accelerating electrode for said beam of electrons, and a collecting electrode for collecting the electrons after their passage past said accelerating electrode, all said means being in said tube in the order named, said collecting electrode comprising a cup-shaped member with its open end in position to receive the beam of electrons, a radially inwardly extending lip at the open end of said cup-shaped member, a ring-like electrode within the collecting electrode and adjacent said lip for providing a field of lower potential than the potential of said collecting electrode, and a rod electrode extending axially of said collecting electrode and adjacent the closed end of the cup-shaped member but insulated therefrom for establishing a field of lower potential than that of said collecting electrode.

7. An electron discharge tube including a pair of tubular coaxial conducting members separated by a gap, a source of electrons positioned along the axis of said tubular conducting members for projecting a beam of electrons past said gap, means for modulating said beam of electrons, and a collecting electrode for collecting the electrons after their passage past said gap, said collecting electrode comprising a cup-shaped member with its open end in position to receive the beam of electrons, a radially inwardly extending lip at the open end of said cup-shaped member, and a rod electrode extending axially of said collecting electrode and adjacent the

closed end of the cup-shaped member but insulated therefrom for establishing a field of lower potential than that of said collecting electrode.

8. An electron discharge tube having a pair of coaxial tubular conducting members separated by a gap, a conducting member surrounding and connected to said pair of tubular conducting members to form an oscillating tank circuit, means positioned along the axes of said tubular conducting members for projecting a beam of electrons past said gap, means for modulating said beam of electrons prior to its passage past said gap, and a collector electrode for collecting electrons on the opposite side of said gap from the electron projecting means, said collecting electrode comprising a cup-shaped member with its open end in position to receive the beam of electrons, an accelerating electrode outside of but adjacent to the open end of said cup-shaped member, and a ring-like electrode within said cup-shaped member and adjacent the open end for providing a field of lower potential than that of said collecting electrode.

9. An electron discharge tube having a pair of coaxial tubular conducting members separated by a gap, a conducting member surrounding and connected to said pair of conducting members to form an oscillating tank circuit, means positioned along the axes of said tubular conducting members for projecting a beam of electrons past said gap, means for modulating said beam of electrons prior to its passage past said gap, and a collector electrode for collecting electrons on the opposite side of said gap from said electron projecting means, said collecting electrode comprising a cup-shaped member with its open end in position to receive the beam of electrons and having an aperture in its closed end, an accelerating electrode outside of but adjacent to the open end of said cup-shaped member, and a ring-like electrode within said cup-shaped member and adjacent the open end for providing a field of lower potential than that of said collecting electrode, and a rod-like electrode extending through the aperture in the closed end of said collecting electrode and axially thereof but out of contact therewith for establishing a field of lower potential than the potential of said collecting electrode and a shield on said rod outside of said collecting electrode for providing an electron shield for the aperture in the closed end of said cup-shaped member.

10. An electron discharge tube having an en-

velope containing a cathode and grid for providing a stream of modulated electrons and a collector electrode spaced from said cathode and grid for receiving said electrons, and a quarter-wave concentric line circuit having a pair of coaxial tubular members spaced axially to provide a gap surrounding said envelope and the discharge path between the cathode and collector electrode with the gap between the tubular members intermediate the grid and the collector electrode, said collector electrode comprising a cup-shaped member with its open end in position to receive the stream of electrons, a ring-like electrode adjacent the open end of said collecting electrode for establishing a field at lower potential than the potential of said collector electrode, and means extending axially of said collecting electrode for establishing a field of lower potential than the potential of said collecting electrode.

11. An electron discharge tube having an envelope having a press and containing a cathode and grid for providing a stream of modulated electrons and a collector electrode spaced from said cathode and grid for receiving said electrons, and a quarter-wave concentric line circuit having a pair of coaxial tubular members spaced axially and providing a gap surrounding said envelope and the discharge path between the cathode and collector electrode and with the gap between the tubular members intermediate the cathode and the collector electrode, said collector electrode comprising a cup-shaped member with its open end in position to receive the stream of electrons and having an aperture in the closed end, a radially extending lip on said collecting electrode at the open end thereof, an accelerating electrode outside of and adjacent the open end of the collecting electrode and coaxial therewith and supported from the press in said envelope, a ring-like electrode inside the collector electrode and adjacent the open end thereof and insulatingly supported within and adjacent the open end of said collector electrode, a connection from said ring extending through said press, a rod-like electrode extending axially of the collector electrode through the aperture in the closed end of said collector electrode and supported from said press, and a shield carried by said rod for shielding said aperture and a support in said press for said collector electrode.

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