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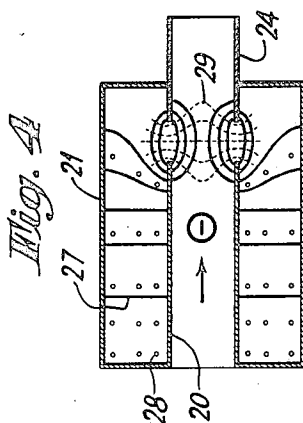
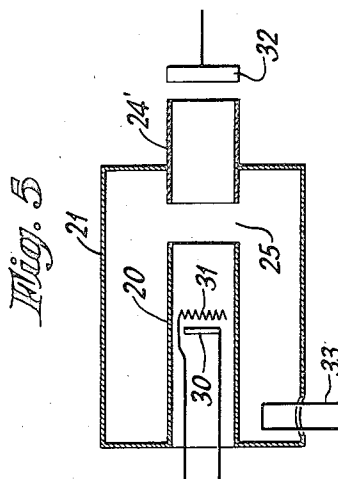
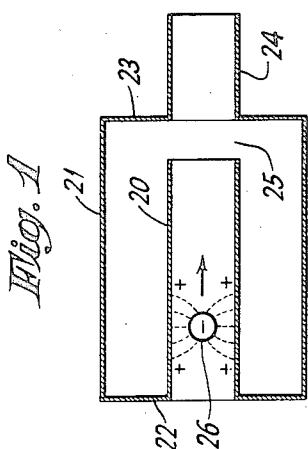
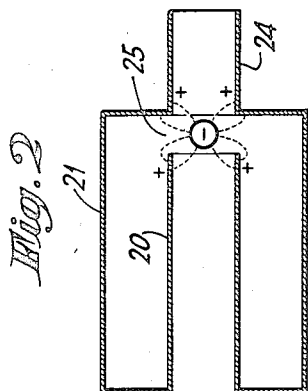
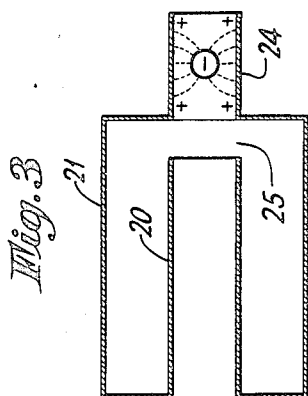
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2,293,387

ELECTRON DISCHARGE DEVICE

Original Filed Feb. 2, 1939

2 Sheets-Sheet 1



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Fig. 6

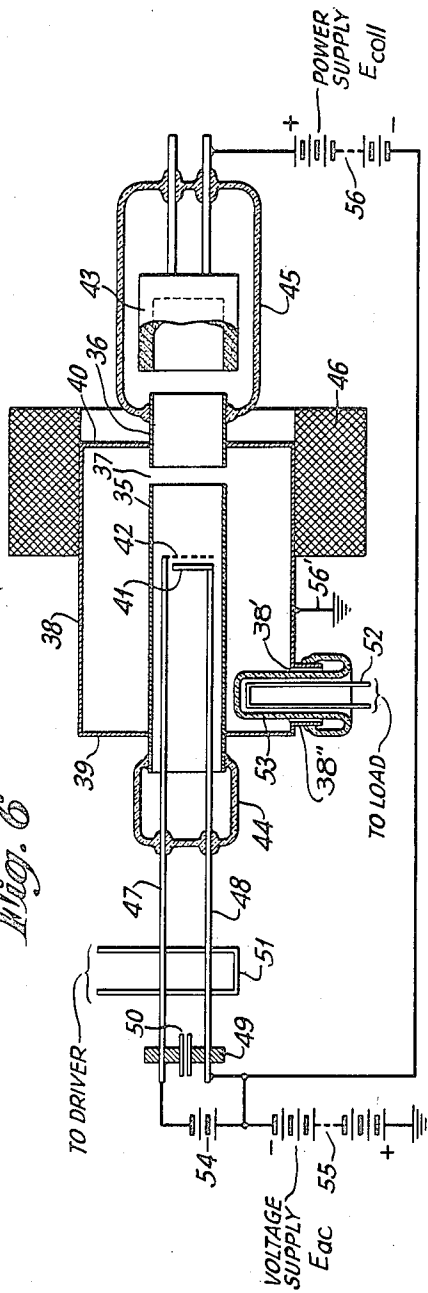
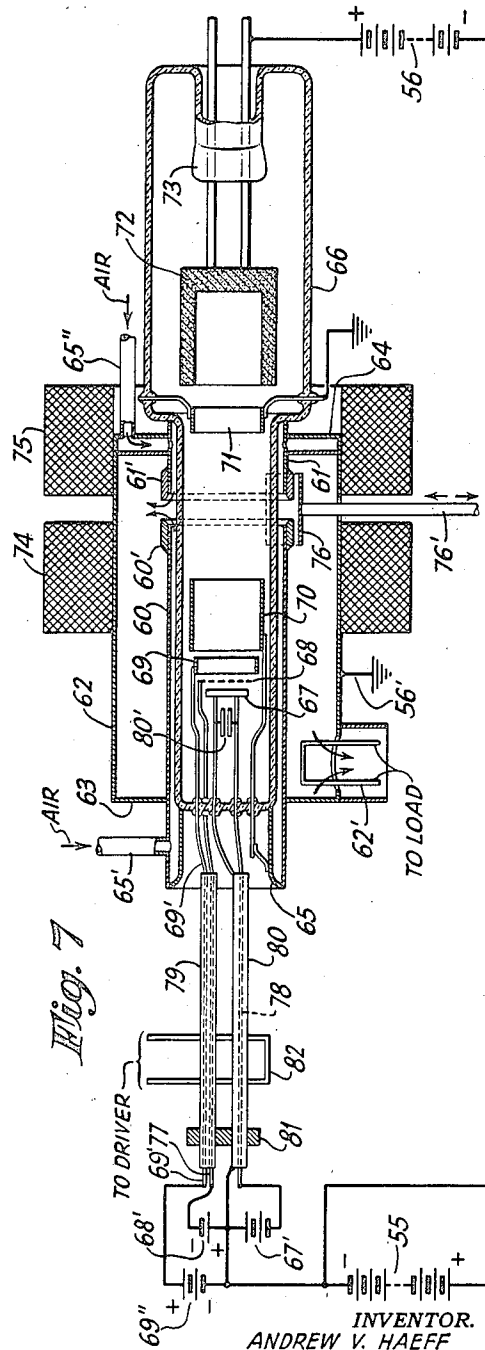


Fig. 7



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## UNITED STATES PATENT OFFICE

2,293,387

## ELECTRON DISCHARGE DEVICE

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254,239. Divided and this application Novem-  
ber 30, 1940, Serial No. 368,065

18 Claims. (Cl. 250—27.5)

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

The present application is a division of my application which issued as United States Patent 2,237,878 on April 8, 1941.

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 transconductance 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.

The principal object of my invention is to provide an improved electron discharge device particularly suitable for use at high frequencies.

More particularly it is an object of my invention to provide an electron discharge device 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.

A further object of my invention is to provide an electron discharge device particularly suitable for use as an amplifier at very high frequencies.

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 made according to my invention, and Figures 6 to 11 inclusive are longitudinal sections of electron discharge devices made according to my invention, the associated voltage sources being shown in Figures 6 and 7.

A better understanding of my invention can be had by discussing the principle involved. To illustrate the principle involved in electron discharge devices made according to my invention 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 equi-potential surfaces in the gap. Along the major part of the length of the tank circuit the direction of the electric field is sub-

stantially 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 resonating 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 effect 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 Figure 6 is shown a tube in longitudinal section and made according to 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 35 and 36 separated axially by a gap 37 and electrically connected to a concentric outer cylinder or tubular member 38 by means of end plates 39 and 40. Mounted within the tubular member 35 is an indirectly heated cathode 41, the heater of which is not shown, and a grid 42. These electrodes may be disc or rectangular shaped. Electrons supplied by the cathode 41 are projected axially within the cylinders 35 and 36 to a collecting electrode 43 preferably of carbon. The glass cup members 44 and 45 close the ends of the tubular members 35 and 36 to provide with the member 38 an envelope for the electrodes, the cup-shaped member 44 being sealed to the tubular member 35 and the cup-shaped member 45 being sealed to the electrode 36 which will be referred to as a screening electrode. The solenoid 46 may be provided for focusing the electrons from the cathode 41 into a well defined beam along the axis of the tubular electrodes 35 and 36. The electrodes 41 and 42 are suitably supported by means of the conductors 47 and 48. A parallel wire transmission line is attached to these conductors. This line forms the input circuit which is tuned by the bridging member 49 provided with the by-passing condenser 50. A loop 51 serves to couple the input circuit to a driver. To permit the tank circuit to be coupled to a load, an aperture 38' is provided in the outer tubular member 38, surrounded by an extension or collar 38''. A reentrant glass portion 53 sup-

ported on and sealed to the extension 38'' is extended through the aperture 38'' in the outer tubular member 38 to permit the insertion of a coupling loop 52 and to seal the tank circuit. The source of voltage 54 connected between the grid and cathode provides a proper bias on grid 42, voltage source 55 being provided for applying to the tank circuit by means of conductor 56 a voltage higher than that applied to the collecting electrode by the power supply 56.

When a high potential  $E_{c0}$  at 58 is applied between the cathode and the electrodes 35 and 36 and a voltage  $E_{c01}$  at 59 between the cathode and collector 43 a stream of electrons from the cathode 41 focused by the magnetic field of the solenoid 40 is projected toward the collector 43 without impinging on either electrode 35 or 36. If a radio frequency voltage is applied between control grid 42 and cathode 41 by exciting the input circuit the electron stream will be periodically modulated in intensity. Pulses of electrons traversing the gap 37 will induce radio frequency currents in the electrodes 35 and 36. If the excitation frequency is adjusted to the resonance frequency of the output circuit 38, 39 and 30 a high impedance will exist across the gap 37 at this frequency. Consequently, currents induced in electrodes 35 and 36 by electron pulses will produce a high radio frequency voltage across the gap 37. 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 35 and outer 36 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 35 and inside the screening electrode 36, a distance effectively less than their diameter so that by positioning the cathode 41, control electrode 42 and the collector 43 at suitable distances from the gap 37, 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 42 and the gap, the electrodes 35 and 36 can be operated at suitable 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  $E_{c0}$  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 35) 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 35 and 36, so that these electrodes dissipate no energy. The power is supplied only by the collector power supply 56.

In Figure 7 is shown an arrangement in which the output electrodes and tank circuit are external to the tube envelope. In this case the inner tubular member or electrode 60 and screening electrode 61 are joined and electrically connected to the outer tubular member 62 by means

of conducting plates 63 and 64. 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 75 movable by insulated rod 76 toward and from the electrodes 60 and 61 to increase or decrease the capacity coupling between these two electrodes. The edges of the electrodes 60 and 61 are thickened and rounded as at 60' and 61' to prevent excessive radio frequency fields at the gap with a consequent dielectric loss in the glass envelope 66 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 65 contacting the glass envelope and forming with the inner tubular members 60 and 61 a hollow tubular casing around the envelope into which air can be forced through tubes 65' and 65'', as indicated. The whole external concentric line tank circuit and the glass envelope can be separated at will. Envelope 66 which fits within the concentric tank circuit is provided with an indirectly heated cathode 67 (heater not shown), control grid 68 and focusing electrode 69, which 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 74 and 75 without undesirable current absorption by the accelerating electrodes 70 and 71 positioned between the cathode and collector electrode 72 supported from the press 73. The reason for using the accelerating electrodes 70 and 71 is to avoid the undesirable effects of charges on the glass wall due to bombardment by stray electrons. The electrodes 70 and 71 are positioned at a suitable distance from the gap between the electrodes 60 and 61 of the output tank circuit so that the radio frequency fields from the space between the tubular members 60 and 62 do not reach them, and thus electrodes 70 and 71 do not form a part of the output circuit and do not carry circulating currents. The electron stream from the cathode 67 modulated by grid 68 focused by the electrode 69 traverses the gap between electrodes 60 and 61. As in the previous case a high radio frequency voltage will be developed across the gap and electrons will be decelerated in the gap and finally after passing accelerating electrode 71 will be collected by means of electrode 72. Radio frequency energy is transferred from the tank circuit by the coupling loop 62' to the load.

A parallel wire transmission line comprising tubular conductors 76 and 80 tuned by a conducting bridge 81 form the input circuit. Conductors 69' and 77 connected to the focusing electrode 69 and grid 68 extend through tubular member 70 and are connected to the voltage sources 80'' and 80' to provide the biasing voltages for the focusing electrode 69 and the grid 68. The tubular member 80 and the insulated conductor 78 within the tubular member furnish the cathode heating current from the source of voltage supply 67' and the conductor 80 acts at the same time as the cathode lead. Adequate by-passing for high frequency currents is provided by the condenser 86', preferably placed inside the glass envelope and

connected between the heater and cathode leads. Radio frequency coupling between the transmission line conductor 79 and 80 and the grid and the focusing electrodes is due to the inherent capacity between these conductors and the insulated loads within the hollow conductor tubes. If necessary, additional condensers for capacity coupling can be provided between the conductor tubes and the leads.

One sample of a tube made according to my invention has an external member 62 of a length of 6" and diameter of 2", the inner tubular members 60 and 61 having a diameter just sufficiently large to permit slipping the concentric line unit over the end of the envelope 66 having an outside diameter of 1 1/4". The gap between the inner tubular member 60 and 61 was of the order of 1/8". The accelerating electrode 71 with a width of 1/2" was spaced 2" from the accelerating electrode 70 having a width of 1", the focusing electrode being spaced 1/8" from the edge of the accelerating electrode 70. The collecting electrode 72 has an outside diameter of 2" and a depth of 2". It is of course understood that these dimensions could be changed or varied for different frequencies and for different power outputs.

The tube was operated under the following conditions: At a frequency of 450 megacycles, power output of 110 watts was obtained, the driving power being about 10 watts and the efficiency about 35%. The accelerating voltage applied to electrode 70 and 71 was of the order of 6000 volts and the collector electrode voltage of the order of 2000 volts. The collector current was approximately 150 milliamperes. The extremely low loss in the accelerating electrodes 70 and 71 is shown by the fact that less than .1 milliamperes was the current to these electrodes. 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 minimized 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.

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 depart-

ing from the scope of my invention as set forth in the appended claims.

What I claim as new is:

1. An electron discharge device including a cathode and grid for supplying a modulated stream of electrons and a collecting electrode for receiving said modulated stream of electrons, and a quarter wave concentric line output tank circuit having a pair of coaxial tubular members axially spaced to provide a gap and surrounding the discharge path between the cathode and anode whereby electrons from the cathode to the anode traverse the gap between said pair of coaxial tubular members, and accelerating means including a pair of electrodes surrounding the path of the beam between the cathode and the collecting electrode.

2. An electron discharge device including an envelope containing a cathode and grid for supplying a modulated stream of electrons and an electrode for collecting electrons in said stream, a tank circuit surrounding said envelope and including a pair of coaxial tubular members spaced axially to form a gap therebetween surrounding the discharge path between the cathode and the collecting electrode, and electromagnetic means surrounding said tubular members for focusing the electrons from the cathode to the collecting electrode into a well-defined beam.

3. An electron discharge device including an envelope containing a cathode and grid for supplying a modulated stream of electrons and an electrode for collecting electrons in said stream, an accelerating means within said envelope and including a pair of electrodes surrounding the path of the electrons between the cathode and collecting electrode, a tank circuit surrounding said envelope and including a pair of coaxial tubular members spaced axially to form a gap therebetween surrounding the discharge path between the cathode and the collecting electrode, and electromagnetic means surrounding said coaxial tubular members for focusing the electrons from the cathode to the collecting electrode into a well-defined beam, and a conductor bridging the gap and overlapping but out of contact with the adjacent ends of the coaxial tubular members and movable transversely of the coaxial tubular members to change the capacity coupling between said coaxial tubular members.

4. An electron discharge device including an envelope having a cathode and grid for supplying a modulated stream of electrons and an electrode for collecting electrons in said stream, and accelerating means within said envelope and including a pair of electrodes surrounding the path of the stream between the cathode and the collecting electrode, a pair of coaxial tubular members spaced axially to form a gap therebetween surrounding the discharge path between the cathode and the collecting electrode, a conducting plate member secured to each of said coaxial tubular members intermediate the ends of the tubular members and electrically connected at their peripheries by a conducting cylindrical member to form a tank circuit and a conductor bridging the gap and overlapping but out of contact with the adjacent ends of the coaxial tubular members and movable transversely to the coaxial members to change the capacity coupling between said members to vary the frequency at which the tank circuit will oscillate.

5. An electron discharge device including an envelope containing a cathode and grid for supplying a modulated stream of electrons and an

electrode for collecting said electrons, a hollow tank circuit surrounding said envelope and having a gap lying in a plane transverse to the stream of electrons and between the grid and collecting electrode, said tank circuit being spaced from said envelope to provide a passageway between the envelope and the tank circuit, and means for directing a cooling medium between the envelope and the tank circuit.

6. An electron discharge device including an envelope containing a cathode and grid for supplying a modulated stream of electrons, and an electrode for collecting the electrons in said stream, an elongated hollow tank circuit surrounding said envelope and including a pair of coaxial tubular members spaced axially to form a gap therebetween surrounding the discharge path between the cathode and the collecting electrode, said tubular members being spaced from said envelope to provide a passageway between the envelope and the tubular members, and means for directing a cooling medium between the envelope and the tubular members into the interior of the tank circuit through said gap, said last means including extensions on opposite ends of said tank circuit and enclosing a space around the envelope, said space communicating with the space between the tank circuit and envelope and having inlets for introducing the cooling medium.

7. An electron discharge device including an envelope containing a cathode and a grid for supplying a modulated stream of electrons, and an electrode for collecting the electrons in said stream, a hollow tank circuit surrounding said envelope and including a pair of coaxial tubular members spaced axially to form a gap therebetween surrounding the discharge path between the cathode and collecting electrode and a conducting member surrounding said coaxial tubular members and secured and electrically connected to each of said coaxial tubular members, said coaxial tubular members being spaced from the envelope to provide an annular passageway between the envelope and the tubular members, inlet means for directing a cooling medium between the envelope and the inner tubular members through said gap into the interior of said tank circuit, said conducting member surrounding said tubular members being provided with an aperture through which the cooling medium can pass to the exterior of the tank circuit.

8. An electron discharge device including an envelope containing a cathode and grid for supplying a modulated stream of electrons and an electrode for collecting the electrons in said stream, accelerating means within the envelope and including a pair of electrodes surrounding the path of the electrons between the cathode and the collecting electrodes, a tank circuit surrounding said envelope and including a pair of coaxial tubular members spaced axially to form a gap therebetween surrounding the discharge path between the cathode and the collecting electrode and a conducting member surrounding said coaxial tubular member and secured and electrically connected to each of said coaxial tubular members, and electromagnetic means surrounding the conducting member for focusing electrons from the cathode to the collecting electrode into a well-defined beam.

9. An electron discharge device including an envelope having a cathode and grid for supplying a modulated stream of electrons and an electrode for collecting electrons in said stream and accelerating means within said envelope and in-

cluding a pair of electrodes surrounding the path of the beam between the cathode and the collecting electrode, a tank circuit surrounding said envelope and including a pair of coaxial tubular members spaced axially to form a gap therebetween surrounding the discharge path between the cathode and the collecting electrode and a conducting plate member secured to each of said coaxial tubular members intermediate the ends of the tubular members and electrically connected at their peripheries by a conducting cylindrical member, and a conductor bridging the gap and overlapping but out of contact with the adjacent ends of the coaxial tubular members and movable transversely of the coaxial members to change the capacity coupling between said members to vary the frequency at which the tank circuit will oscillate, and electromagnetic means surrounding each of the coaxial tubular members.

10. An electron discharge device including a cathode and grid for supplying a modulated stream of electrons, and a collecting electrode for collecting electrons in said stream, and a hollow tank circuit surrounding said stream of electrons and including a pair of coaxial tubular members spaced axially to form a gap therebetween surrounding the discharge path between the cathode and collecting electrode and a conducting plate member secured to each of said coaxial tubular members intermediate the ends of the tubular members and a conducting member electrically connecting said plates at their peripheries, and electromagnetic means surrounding said tubular members for focusing the electrons projected from the cathode to the collecting electrode in a well-defined beam, said conducting member electrically connected to the peripheries of the conducting plate members having an aperture and a reentrant extension of insulating material extending within said aperture and sealing said tank circuit, and a conducting loop extending within the reentrant insulating extension for coupling the electron discharge device to an output circuit.

11. An electron discharge device having a cathode for supplying a stream of electrons and means for collecting said electrons, a hollow tank circuit having a passageway extending there-through through which the electrons from the cathode pass to the collecting means, said passageway having a gap surrounding the discharge path between the cathode and the collecting means, an insulating means closing one end of the passageway to provide with the hollow tank circuit an envelope for the cathode, said hollow tank circuit having an aperture extending through the outer surface thereof, and an insulating closure member supported within said aperture and sealing said aperture in said hollow tank circuit, and a conducting coupling member extending within the hollow tank circuit through said aperture.

12. An electron discharge device having a cathode for supplying a stream of electrons and means for collecting said electrons, a hollow tank circuit having a passageway extending there-through through which the electrons from the cathode pass to the collecting means, said passageway having a gap surrounding the discharge path between the cathode and the collecting means, an insulating means closing one end of the passageway to provide with the hollow tank circuit an envelope for the cathode, said hollow tank circuit having an aperture extending through the outer surface thereof and an ex-

tension around said aperture, and an insulating closure member supported by said extension and sealing said aperture in said hollow tank circuit, and a conducting coupling member extending through the extension within the hollow tank circuit.

13. An electron discharge device having a cathode and grid for supplying a modulated stream of electrons and means for collecting said electrons, a hollow tank circuit having a passageway extending therethrough through which the electrons from the cathode pass to the collecting means, said passageway having a gap surrounding the discharge path between the cathode and the collecting electrode, and insulating means closing one end of the passageway to provide with the hollow tank circuit an envelope for the cathode and grid, said hollow tank circuit having an aperture extending through the outer surface thereof and an extension around said aperture and insulating material supported by said extension and sealing said aperture in said tank circuit and a conducting coupling member extending through the extension within the hollow tank circuit.

14. An electron discharge device having a tank circuit comprising a hollow body formed by a surface of revolution and having a resonant frequency and having a passageway extending through said hollow body, said passageway having a gap extending entirely around said passageway and in a plane transverse to said passageway, a cathode for supplying electrons axially of said passageway past said gap, and means for collecting the electrons after the passage of electrons past said gap, insulating cup-shaped members closing the opposite ends of said passageway and providing with said hollow body an envelope for said cathode and collecting electrode, the outer surface of said hollow body being provided with an aperture and a reentrant extension of insulating material extending within said aperture and sealing said hollow body, and a conducting coupling member extending within the reentrant insulating extension and said hollow body.

15. An electron discharge device including a hollow output tank circuit having a pair of coaxial tubular members spaced axially to form a gap and a conducting member surrounding said tubular members and conductively secured to said coaxial tubular members, a cathode and grid positioned adjacent one end of one of said coaxial tubular members for supplying a modulated stream of electrons axially of said coaxial tubular members across said gap and a collecting electrode adjacent an end of the other tubular member for receiving the electrons from the cathode after passage across said gap and cup-

shaped insulating members closing the opposite ends of the coaxial tubular members to form with said hollow output tank circuit an envelope for said cathode, grid and collecting electrode, and a reentrant extension of insulating material extending within said aperture and said hollow output tank circuit and sealing said tank circuit, and conducting coupling means extending within the reentrant insulating extension.

16. An electron discharge device having a cathode for supplying a stream of electrons and means for collecting said electrons, a hollow tank circuit having a passageway extending therethrough through which the electrons from the cathode pass to the collecting means, said passageway having a gap surrounding the discharge path between the cathode and the collecting means, means closing one end of the passageway to provide with the hollow tank circuit an envelope for the cathode, said hollow tank circuit having an aperture extending through the outer surface thereof, and a cup-shaped insulating closure member extending within said aperture and sealing said aperture in said hollow tank circuit, and a conducting coupling member within the hollow tank circuit extending through said aperture.

17. An electron discharge device having a cathode for supplying a stream of electrons and means for collecting said electrons, a hollow tank circuit having a passageway extending therethrough through which the electrons from the cathode pass to the collecting means, said passageway having a gap surrounding the discharge path between the cathode and the collecting means, insulating means closing one end of the passageway to provide with the hollow tank circuit an envelope for the cathode, said hollow tank circuit having an aperture extending through the outer surface thereof, and a reentrant insulating closure member extending within said aperture and sealing said aperture to said hollow tank circuit, and a conducting coupling member within the hollow tank circuit extending through said aperture.

18. An electron discharge device having a cathode and grid for supplying a modulated stream of electrons and an electrode for collecting said electrons, a hollow tank circuit surrounding said stream of electrons and having a gap lying in a plane transverse to the stream of electrons and between the grid and collecting electrode, and a pair of accelerating and screening electrodes positioned between the grid and the collector electrode, one of the accelerating and screening electrodes being positioned on each side of said gap.

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