

Dec. 23, 1947.

A. V. HAEFF

2,433,044

ELECTRON DISCHARGE DEVICE

Filed April 24, 1942

3 Sheets-Sheet 1

Fig. 1.

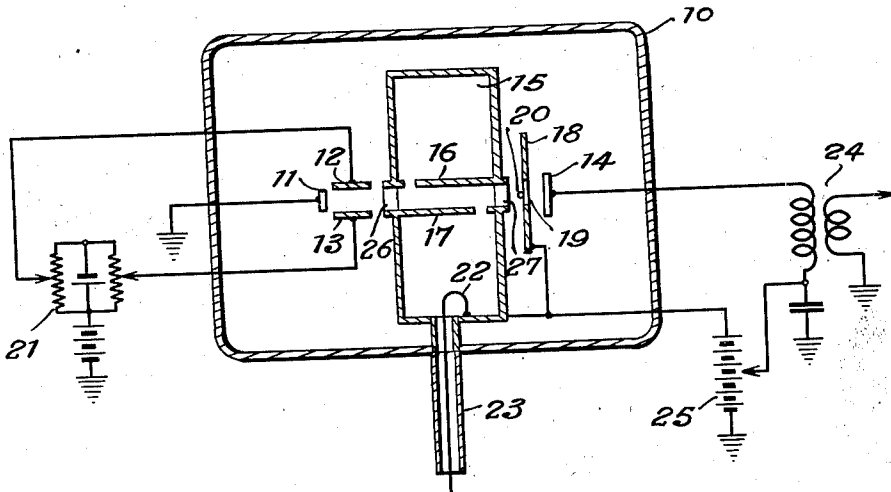
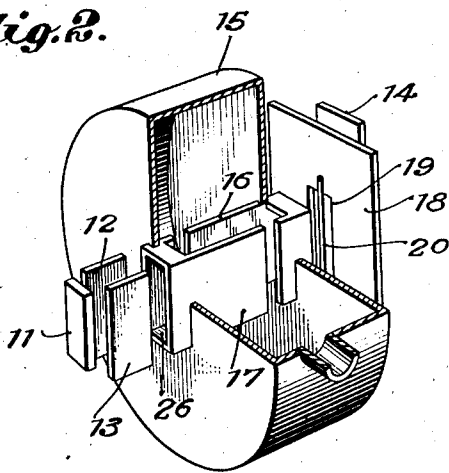


Fig. 2.



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Fig. 3.

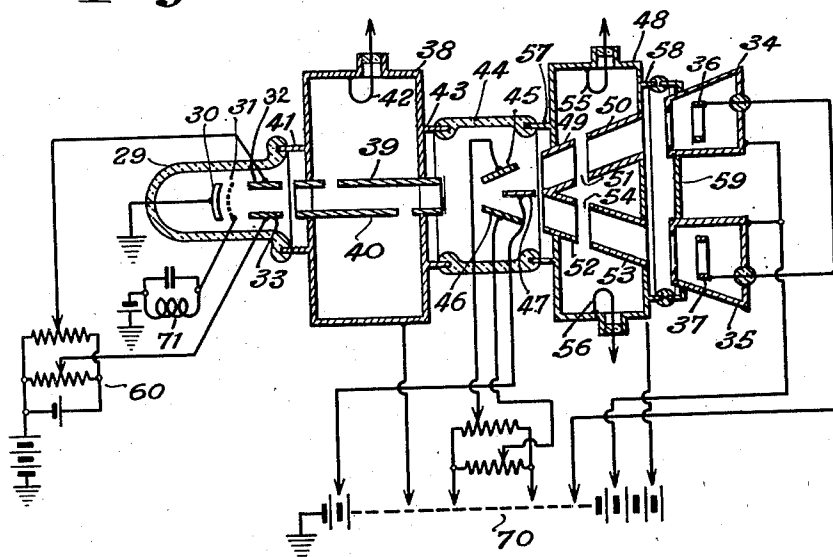
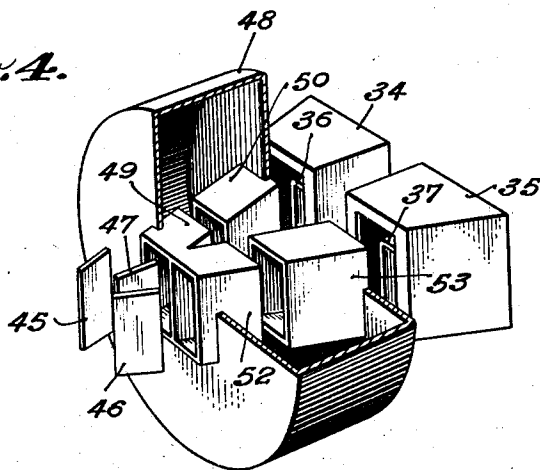


Fig. 4.



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Fig. 5.

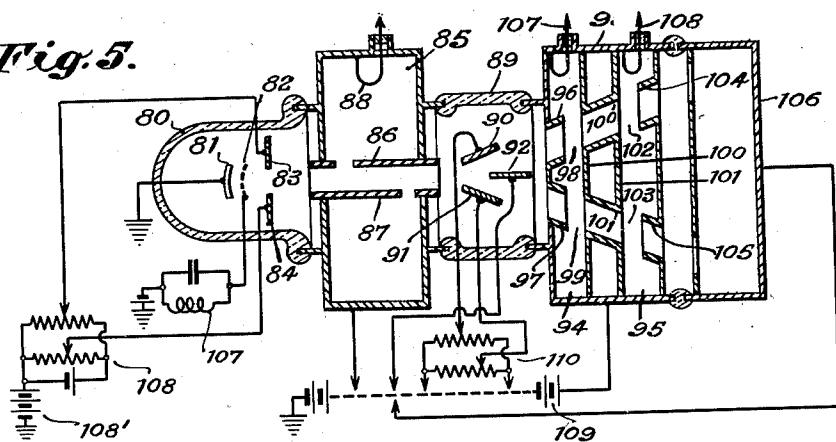


Fig. 6.

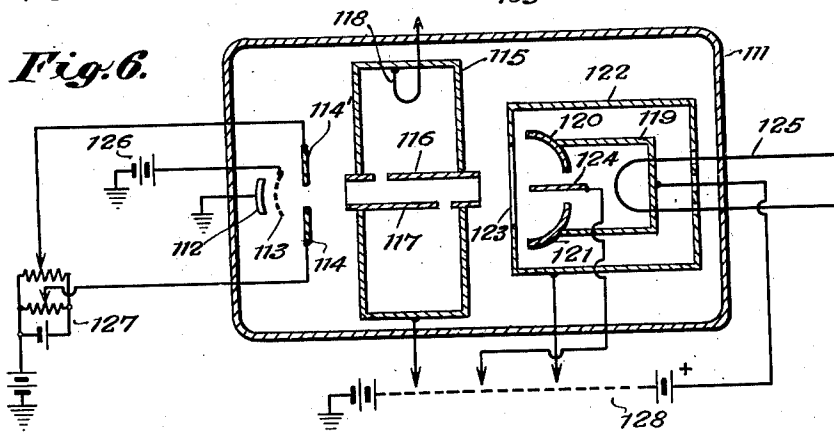
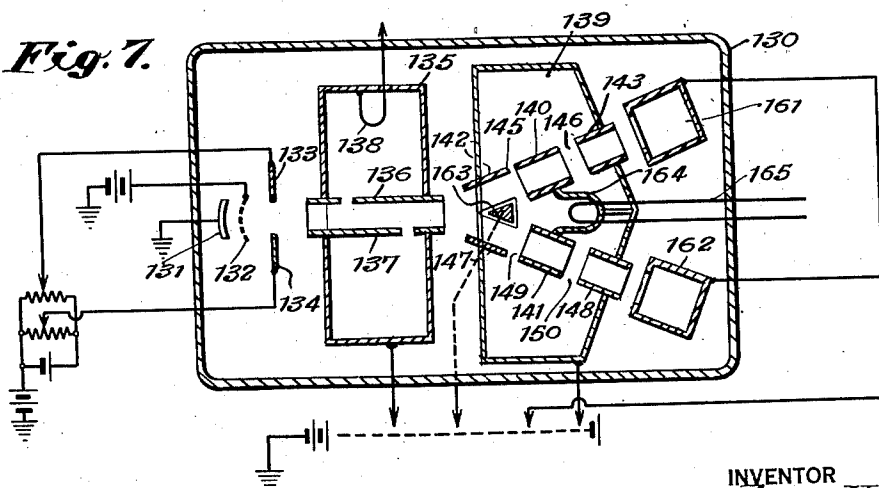


Fig. 7.



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ELECTRON DISCHARGE DEVICE

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Application April 24, 1942, Serial No. 440,297

7 Claims. (Cl. 250—27.5)

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My invention relates to electron discharge devices, more particularly to such devices utilizing electron beam deflection and useful at ultra high frequencies.

In conventional tubes utilizing beam deflection, a beam of electrons is directed from the cathode between a pair of deflecting electrodes toward an apertured electrode behind which is placed an electron collector. Alternating radio frequency voltages are applied to the deflecting electrodes to cause the electron beam to be deflected across the apertured electrode, thus to control the amount of current to the collector, which may be used as an output electrode. In such types of tubes the deflection sensitivity drops off as the frequency at which the tube is operated is increased; that is the transconductance of the tube decreases. Tubes of this kind are also subject to the limitation of the usual conventional tubes in that when operated at ultra high frequencies the presence of considerable loading in the input circuit results in an excessive amount of power being required to drive the tube. This decreases the effective power gain of the tube when operated as an amplifier.

Fundamental causes of high input loading are, among other things, ohmic and radiation losses due to high circulating currents in electrodes and leads. Electron loading also results from the interaction of the electron stream and the circuits connected to tube electrodes, and may include degenerative or regenerative effects caused by common lead impedances.

It is an object of my invention to provide an electron discharge device of the beam deflection type which is particularly suitable for use at high frequencies and which has a comparatively high transconductance.

It is another object of my invention to provide such a device utilizing an input circuit in which input loading is minimized, thus making more effective use of the driving power.

A still further object of my invention is to provide an electron discharge device of the beam deflection type useful at ultra high frequencies and which employs low loss input and output electrode systems and circuits.

A further object of my invention is to provide such a device in which undesired coupling, due to common leads and ineffective shielding, is reduced to a minimum.

Another object of my invention is to provide an electron discharge device of the beam deflection type useful at ultra high frequencies as an amplifier, oscillator or a mixer.

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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 Figure 1 is a schematic longitudinal section of an electron discharge device made according to my invention and its associated circuit, Figure 2 is a perspective, partly in section, of the electrode system utilized in the device shown in Figure 1, Figure 3 is a schematic longitudinal section of a modification of an electron discharge device made according to my invention and its associated circuit, Figure 4 is a perspective, partly in section, of the output tank circuit utilized in the electron discharge device shown in Figure 3, Figures 5, 6 and 7 are schematic longitudinal sections of other modifications of my invention.

As shown in Figure 1, an electron discharge device made according to my invention comprises an envelope 10 having at one end a cathode 11, which may be indirectly heated, and a pair of accelerating and focusing electrodes 12—13, and at the other end a collector 14 for receiving electrons. In accordance with my invention, I position between the focusing electrode and the collector a resonant cavity tank circuit or resonator 15 having a pair of oppositely disposed deflecting elements 16—17 positioned adjacent to and electrically connected to and supported by opposite walls of the cavity adjacent the apertures 26 and 27. Positioned between the resonant cavity and the collector is the conducting plate-like member 18 having an elongated aperture 19 and centrally positioned a conducting rod 20 for thus providing a double aperture. Preferably the length of the overlapping portions of the deflecting elements 16 and 17 is equal to the distance travelled by an electron during a half period of the applied controlling voltage while the tube is in operation. It has been found that this provides maximum deflection sensitivity.

A biasing voltage divider arrangement for the deflecting electrodes is shown at 21 and the output is taken between collector 14 and apertured conducting member 18 by means of the output transformer 24. Voltage sources for the various electrodes are shown at 25. The input coupling loop 22 within the resonator 15 is connected to a coaxial transmission line 23.

In operation the biasing or polarizing voltages are applied to electrodes 12—13 to focus and properly direct electrons through the elongated aperture of the resonant cavity tank circuit 15.

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In passing through the resonant cavity the beam is subjected to a transverse alternating field between the elements 16 and 17 and deflected across apertured element 18, the electrons being collected at 14, the double aperture in element 13 giving a desired control voltage-anode current characteristic.

The resonator is maintained energized by means of the input line 23 and coupling loop 22. In one mode of excitation an electromagnetic field is set up within the cavity such that the magnetic lines of force are approximately concentric with and coaxial with the cavity. The radio frequency currents circulate alternately from one side of the inner surface of the cavity to the other between the apertures, causing each of the deflecting elements 16 and 17 to receive a voltage thereon approximately equal to the voltage appearing at the aperture adjacent which the element is connected, so that the electron stream is subjected to a deflecting electric field.

In the modification shown in Figure 3 which utilizes a push-pull output resonator, the input circuit is substantially the same as that shown in Figure 1. Mounted at one end of the envelope of which the resonators form part is an elongated cup-shaped insulation member 29 enclosing cathode 30, accelerating or modulating grid 31, and focusing and accelerating electrodes 32 and 33, the cup-shaped member being fused to the collar 41 of the resonant cavity tank circuit 38. The resonant cavity tank circuit is energized by means of coupling loop 42 so that a deflecting voltage appears across electrodes 39 and 40 as explained above. Following this resonant cavity 38 is a beam-directing and separating electrode system housed within the insulating collar portion 44 fused to the collar 43 of resonator 38 and collar 57 of resonator 48. Electrode 47 maintained at a lower potential than the accelerating and directing electrodes 45 and 46 insures that the beam is directed into one or the other of the two passageways provided in the resonant cavity 48. The resonant cavity 48 is provided with reentrant tubular extensions 49 and 50 separated by gap 51, and 52 and 53 separated by gap 54, the output being taken by means of coupling loops 55 and 56. A collar 58 supports a collector system comprising cup-shaped members 34-35 having mounted therein secondary electron suppressors 36 and 37, the envelope being sealed by means of the plate 59, supporting members 34 and 35.

The modulating circuit 71 may be utilized to modulate the stream before entrance of the beam into the deflecting resonator or it may be utilized simply as an accelerator. The biasing voltage and divider source is shown at 60 for biasing and focusing electrode elements 32 and 33. As in the first case the beam of electrons is deflected in passing between electrodes 39 and 40 so as to pass between electrodes 47 and 46, or 45 and 47, and in passing across either of the gaps 51 or 54 excites the resonant cavity 48. In the mode of oscillation utilized, each half of the resonator oscillates at a phase differential of 180° with respect to the other half so that the beam will always be decelerated in passing over gap 51 or gap 54 to maintain the resonator energized. This results in a push-pull output which can be extracted by means of the coupling loops 55 and 56. The manner in which the resonator 48 is caused to be energized by inductive action is now well understood and is described in my earlier Patent 2,237,878, issued April 8, 1941.

In the modification shown in Figure 5 I utilize

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a double cavity for successively extracting energy from the beam passing through this cavity. The insulating cup-shaped member 80 contains cathode 81 and grid 82, as well as the focusing and accelerating electrodes 83 and 84. The electron beam again passes through the deflecting resonant cavity tank circuit 85 driven by coupling loop 88 and having deflecting electrodes 86 and 87 through which the beam is directed and by which the beam is deflected. The beam is directed either between electrodes 90 and 92 or 91 and 92 positioned within the collar member 89. Electrodes 90 and 91 act with the electrode 92, which is the separating electrode held at a potential lower than electrodes 90 and 91, to direct the beam through one or the other of the two paths through the output resonant cavity tank system 93. This system comprises a pair of cavities 94 and 95 having reentrant portions 96, 97, 104 and 105 and having a separating chamber formed by partitions 100, 101 having passageways 100' and 101' extending therethrough. The resonant cavities are energized when the beam passes gaps 98 and 102 and 99 and 103. Energy is extracted from the resonant cavity tank circuits 94 and 95 by means of coupling loops 107 and 108 and the electrons collected by means of the cup-shaped member 106. The modulating circuit is shown at 107 for the grid, and the voltage divider and voltage source 108 is provided for accelerating electrodes 83 and 84. A voltage source 109 provides the necessary voltages for other electrodes and the voltage divider system 110 permits adjustment of the voltage on the beam directing electrodes 90, 91 to properly insure that the beam will travel through the proper passageway. Cavities 94-95 are separate and distinct and separated by the apertured partitions 100 and 101, the transit time of the electrons being matched to the output system such that the electrons are subjected to a decelerating field at gaps 98 and 102, and 99 and 103 in passing through the output system. This requires that the transit time of the electrons through elements 100 and 101 be equal to approximately one-half period, assuming that resonant cavity tank circuits 94 and 95 are operating 180° out of phase. Of course this arrangement need not be used and the electron transit time through 100 and 101 can be made more or less if a different phase relationship is desired between the voltages induced in cavities 94 and 95. The mode of oscillation for each of the cavities 94 and 95 is the same as for cavity 48 in Figure 3.

In the modification shown in Figure 6 I employ a push-pull system in the output utilizing a Lecher wire arrangement and a double anode or collector system. In this arrangement envelope 111 has at one end cathode 112, accelerating grid 113 and accelerating and focusing electrodes 114 and 114', the resonant cavity 115 being driven by coupling loop 118, which is provided with deflecting electrodes 116 and 117. Electrons are directed into the shielded output system comprising anode electrodes 120 and 121 connected together by Lecher wire system 119, the separating electrode 124 being maintained at a lower potential than electrodes 120 and 121 and Lecher wire system 119. This whole arrangement is shielded by means of shielding compartment 122 and energy inductively extracted by means of coupling loop 125. The voltage sources for properly biasing or polarizing are shown at 126, 127 and 128. Since electrodes 120 and 121 operate 180° out of phase, the deflection of the electron beam from

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one to the other of these two electrodes can be properly phased to drive the output system.

In Figure 7 I show a still further modification of my invention utilizing a doubly decelerating output circuit mounted within a cavity. Here envelope 130 has mounted at one end cathode 131, accelerating electrode 132 and accelerating and focusing electrodes 133 and 134. The resonant cavity 135 driven by coupling loop 138 is provided with deflecting electrodes 136 and 137 for bringing about a deflection of the beam generated by the cathode electrode system.

The output system comprises the enclosed conducting structure 139 provided with reentrant portions 142, 147, 143 and 148, which with the tubular electrodes 140 and 141 provide a double set of gaps 145 and 146, and 149 and 150, the separating electrode 163 extending through the bottom of the envelope and being maintained at a lower potential than the conducting enclosure and the elements within the enclosure. The beam in passing, for example, through the tubular member 140 to the collector 161 is subjected to a double deceleration, giving up energy at gaps 145 and 146 in a manner now well known and in accordance with the principles set forth in my patent above referred to. Since the tubular elements 140 and 141 extract energy from the stream 180° out of phase with each other, they may be properly coupled by means of loop 164, which in turn is coupled to output loop 165 extending through envelope 130 and within enclosed conducting member 139. Thus this latter arrangement provides a push-pull double decelerating device in combination with a resonant cavity circuit system for deflecting the electron beam.

In all arrangements above described the input circuit which comprises the resonant cavity tank circuit or resonator is a circuit of low loss both from the standpoint of resistance and radiation losses. Loss of deflection sensitivity due to design of the deflecting electrodes is at a minimum and the output and input circuits because of the enclosed fields are completely shielded from each other and because of the absence of common leads there is substantially no reaction or interaction between the input and output systems. If desired the forms shown in the figures could be utilized as well for mixers by applying a local oscillator voltage, for example, either to the grid electrodes 31 and 81, as shown in Figures 3 and 5, or both local oscillator and signal voltage could be applied to coupling loops 42 and 88, for example. In either case both voltages could be utilized for bringing about intermediate frequency voltages in the output system.

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 device having cathode means for supplying a beam of electrons, a cavity resonator positioned adjacent said cathode means and having oppositely disposed apertures in opposite walls thereof through which the beam path lies and deflecting electrode elements within said cavity resonator and separate from but elec-

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trically connected to opposite walls of the cavity resonator and adjacent each of said apertures and having portions oppositely disposed between which said beam path lies, and an output cavity resonator in the path of said electrons and having a pair of apertures in one wall thereof for directing the beam of electrons alternately through said apertures during operation of said electron discharge device.

2. An electron discharge device having cathode means for supplying a beam of electrons, and a cavity resonator positioned adjacent said cathode means and having oppositely disposed apertures in opposite walls thereof through which the beam path lies, and deflecting electrode elements separate from but electrically connected to opposite walls of the cavity resonator and adjacent each of said apertures and having portions oppositely disposed between which said beam path lies, and an output cavity resonator in the path of said electrons and having a pair of apertures in one wall thereof for directing the beam of electrons alternately through said apertures during operation of said electron discharge device, and means positioned between said cavity resonators including a beam directing electrode system for assisting and directing the beam of electrons into one or the other of the apertures of the output cavity resonator.

3. An electron discharge device having cathode means for supplying a beam of electrons, and a cavity resonator positioned adjacent said cathode means and having oppositely disposed apertures in opposite walls thereof through which the beam path lies, and deflecting electrode elements separate from but electrically connected to opposite inner walls of the cavity resonator and adjacent each of said apertures and having portions oppositely disposed between which said beam path lies, and an output cavity resonator having a pair of apertures in one wall thereof, the beam of electrons being directed alternately through said apertures during operation of said electron discharge device, and an electrode system positioned between said cavity resonators comprising a pair of accelerating and directing electrodes oppositely disposed, and another electrode between said oppositely disposed electrodes for separating the electron beam during operation of the electron discharge device.

4. An electron discharge device having cathode means for supplying a beam of electrons, a cavity resonator positioned adjacent said cathode means and having oppositely disposed apertures in opposite walls thereof through which the beam path lies, and deflecting elements separate and distinct from but electrically connected to opposite walls of the cavity resonator and adjacent each of said apertures and having portions oppositely disposed between which said beam path lies, and an output cavity resonator having a pair of apertures in one wall thereof for receiving the beam of electrons alternately through said apertures during operation of said electron discharge device, said output cavity resonator having reentrant portions extending toward each other but separated by a gap across which the electron beam is to be directed.

5. An electron discharge device having cathode means for supplying a beam of electrons, and a collector means forming an electron path therebetween, and a cavity resonator positioned between said cathode means and said collector means and having oppositely disposed apertures in opposite walls thereof through which the beam

path lies, and deflecting electrode elements electrically connected to opposite walls of the cavity resonator and adjacent each of said apertures and having portions oppositely disposed between which said beam path lies, and an output cavity resonator having a plurality of pairs of oppositely disposed apertures in opposite walls thereof for directing the beam of electrons alternately through different pairs of said apertures during operation of said electron discharge device, said collector means including a cup-shaped member, and means positioned within said cup-shaped member for suppressing secondary electrons.

6. An electron discharge device including a cathode means for providing a beam of electrons, and collector electrode means forming an electron path therebetween, a cavity resonator positioned adjacent said cathode means and having a pair of oppositely disposed apertures in opposite walls through which the beam path lies, a pair of deflecting electrodes within the cavity resonator positioned adjacent said apertures and between which said beam path lies, collars on opposite outside walls of said cavity resonator surrounding said apertures, and a cup-shaped member enclosing said cathode means sealed to one of said collars, a second cavity resonator provided with a collar, and an insulating tubular member sealed between said last collar and the other collar on said first cavity resonator, and a beam directing and separating system within said tubular member, said second cavity resonator being provided with two pairs of oppositely disposed apertures through which the electron beam is to be

alternately directed, and means sealing said collector electrode means to said second cavity resonator providing an evacuated chamber for said cathode means and collector electrode means.

7. An electron discharge device having cathode means for supplying a beam of electrons, a cavity resonator positioned adjacent said cathode means and having oppositely disposed apertures in opposite walls thereof through which the path of said beam of electrons is directed, and a pair of deflecting elements within the cavity resonator positioned adjacent said apertures and connected to the inner walls thereof and between which the path of said beam of electrons is directed, and an output cavity resonator system having a pair of apertures in one wall thereof, the beam of electrons being directed alternately through said apertures during operation of said electron discharge device.

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