

Dec. 24, 1946.

D. O. NORTH

2,413,244

ELECTRON DISCHARGE DEVICE

Filed June 30, 1943

3 Sheets-Sheet 1

Fig. 1.

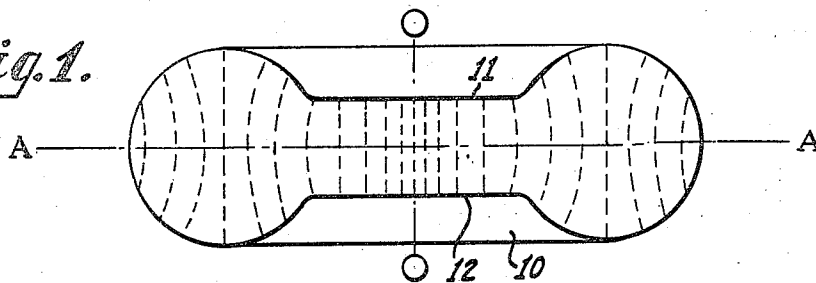


Fig. 2.

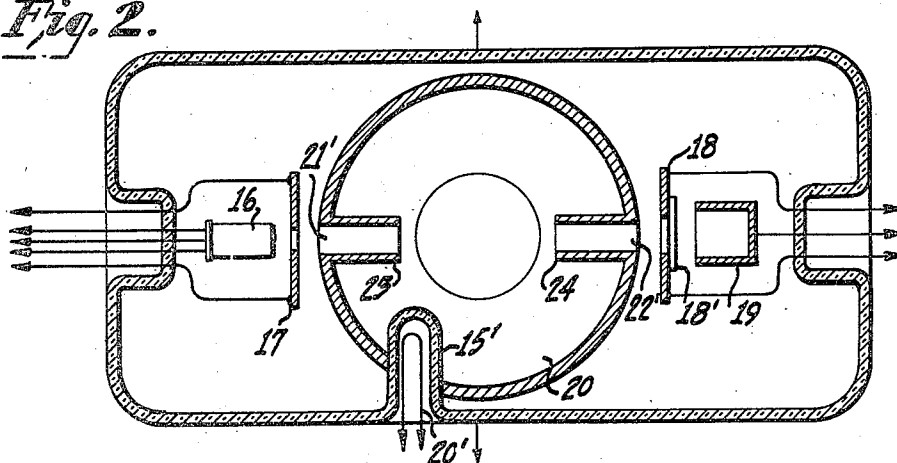
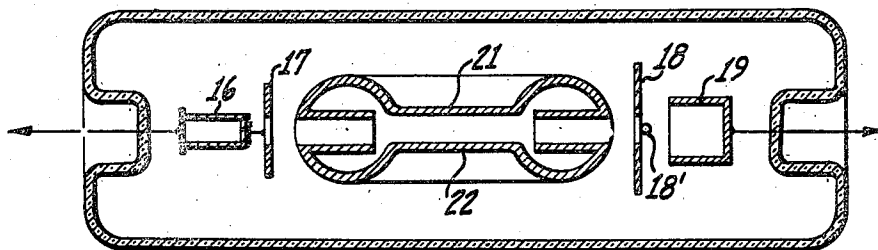


Fig. 3.



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3 Sheets-Sheet 2

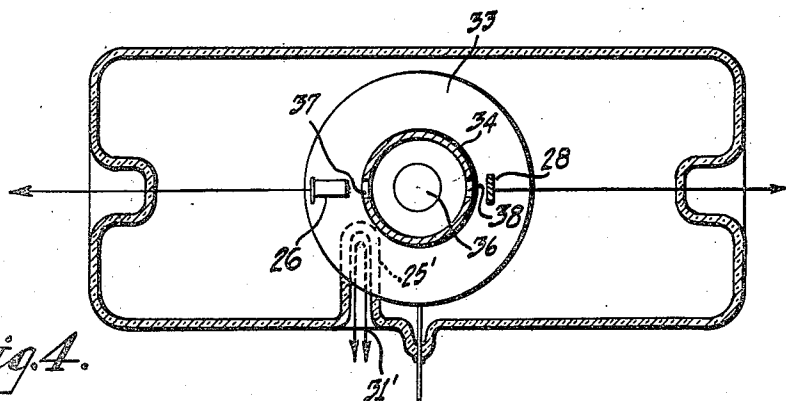


Fig. 4.

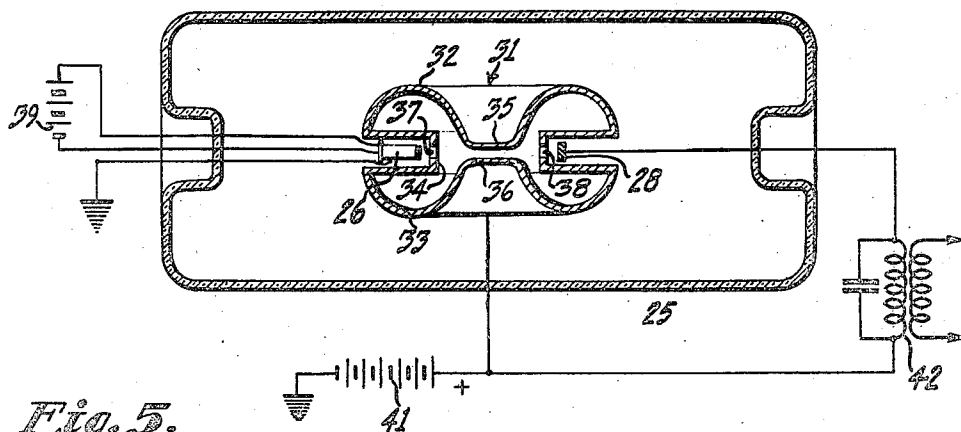


Fig. 5.

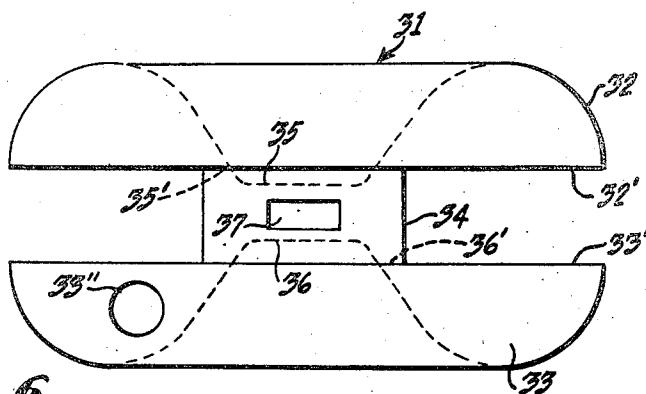


Fig. 6.

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3 Sheets-Sheet 3

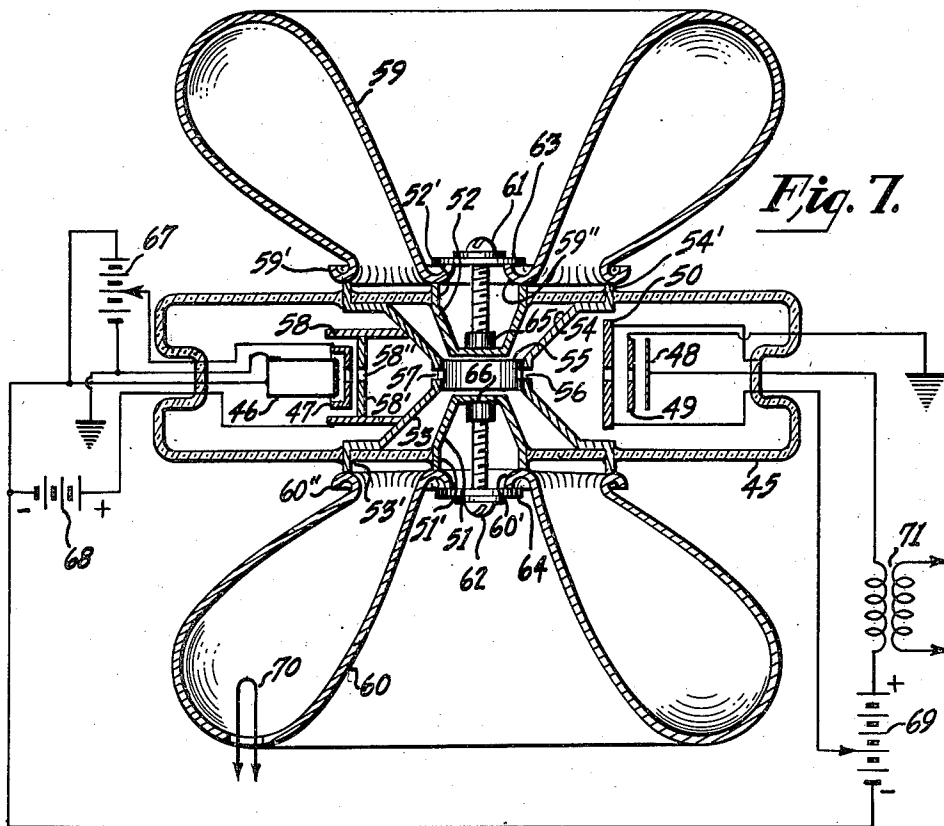


Fig. 7.

Fig. 8.

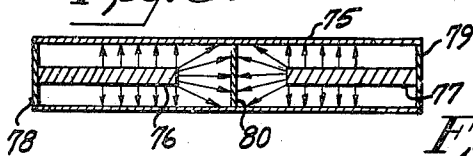


Fig. 9.

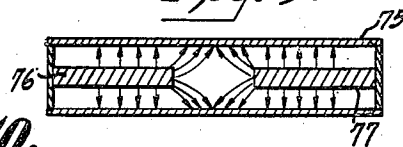


Fig. 10.

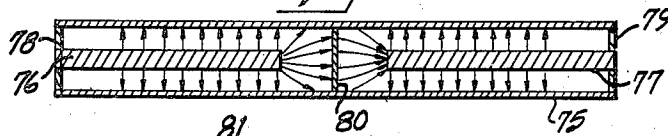
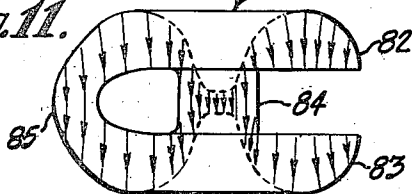


Fig. 11.



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ELECTRON DISCHARGE DEVICE

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4 Claims. (Cl. 250—27.5)

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My invention relates to electron discharge devices useful at ultra high frequencies and more particularly to such devices utilizing electron beams directed through cavity resonators.

In electron discharge devices utilized for ultra high frequency operation the problem of noise is serious and in the design of such devices a chief concern is the provision of large signal-to-noise ratio; that is, a low noise factor.

The use of hollow conducting bodies or cavity resonators in combination with electron discharge devices when used at ultra high frequencies has become common practice due to the peculiarly suitable characteristics of these cavity resonators at these high frequencies. A cavity resonator may be electrically excited by means of the passage of a beam of electrons through the resonator. Variations in current density of the electron beam will induce currents and hence electric fields within the resonator corresponding to the variations in the current density of the beam. The excitation of the resonator by these initial current density variations, particularly the relatively strong field excitations of frequencies near cavity resonance will in turn effect velocity modulation of the electron stream passing through the resonator and may augment the original current density variations of the beam. If the initial or pre-existing current density modulation is in the first place due to noise caused by shot effects within the electron beam, this noise thereby becomes augmented in the output of the tube.

It has also been suggested that the resonator be used for deflecting a beam passing through the resonator. The requirements for maximum deflection sensitivity are such that the effects of induced noise as described are likely to be the greatest when maximum deflection sensitivity is provided for, that is, when the transit time of the electron through the resonator is equal to about one-half the period of the resonator. These noise voltages which are amplified within the resonator may cause a significant and sometimes major portion of the total noise produced by the entire receiving system.

It is therefore an object of my invention to provide an electron discharge device useful at ultra high frequencies in which the signal-to-noise ratio is high, that is, the noise factor is low.

Another object of my invention is to provide an electron discharge device useful at ultra high frequencies and having improved characteristics and utilizing cavity resonators through which a beam of electrons may be directed.

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More specifically it is an object of my invention to provide an electron discharge device of the beam deflection type useful at ultra high frequencies and employing cavity resonators but in which the induced input noise is eliminated or reduced to a negligible value.

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 Figure 1 is a schematic diagram illustrating the principles of my invention; Figure 2 is a longitudinal section of one form of electron discharge device made according to my invention; Figure 3 is a longitudinal section of Figure 2 taken at 90° with respect to Figure 2; Figure 4 is a longitudinal section of a modification of an electron discharge device made according to my invention; Figure 5 is a longitudinal section taken at 90° with respect to Figure 4; Figure 6 is an enlarged view of the cavity resonator used in the device shown in Figures 4 and 5; Figure 7 is a longitudinal section of a still further modification of an electron discharge device made according to my invention and its associated circuits; Figures 8, 9 and 10 are diagrams illustrating certain principles of operation; and Figure 11 is a schematic diagram of a modified form of cavity resonator which may be utilized in the device shown in Figures 4 and 5.

As pointed out above, the object of the present invention is to provide an electron discharge device employing a cavity resonator which will produce deflection of a beam of electrons traversing it but which will not be excited by pre-existing current density modulation or variation in the beam. Mathematically it can be shown that to meet this requirement the integral $\int \bar{E} \cdot d\bar{l}$ of an electron traversing the cavity must approach zero. In this integral $\bar{l}$ is the vector position of the electron, and $\bar{E}$ is the oscillating electric field vector which exists at the electron when the cavity resonator is filled with radiation at the operating (resonance) frequency. In order to fulfill the above condition, the electron should be made to move through a region of the cavity resonator in which the field strength $\bar{E}$ is preferably large but essentially everywhere at right angles to the electron beam.

In Figure 1 is shown a section of a resonator 10 having re-entrant portions 11 and 12, the resonator surfaces being defined by the surface

of revolution of a geometric figure about the axis O—O. The dotted lines represent the $\vec{E}$ lines or oscillating electric field lines within the resonator at an arbitrary instant indicating a possible mode of operation which yields large $\vec{E}$ in the central region between the surfaces of the re-entrant portions 11 and 12. The imaginary plane A—A is transverse to the axis of revolution O—O of the resonator. The imaginary plane AA divides the resonator into two structurally identical resonators oscillating in antiphase. Moving an electron in the plane A—A fulfills the condition described above.

For a practical device it is desirable to move the electrons through the central region where $\vec{E}$ is large. An electron discharge device incorporating a practical form of this type of resonator is disclosed in Figures 2 and 3. An indirectly heated cathode 16 of the type employed for generating an electron beam has mounted adjacent to it an electrode 17 for defining the beam and directing it through the resonator 20 to an apertured electrode 18 and a collector 19. The rod 18' may bisect the aperture in electrode 18 to provide a double aperture to obtain certain desired output characteristics.

The resonator is of the form shown in Figure 1 and has re-entrant portions 21 and 22, the inner surfaces of which are oppositely disposed and lie in parallel planes parallel to the path of the beam between the cathode and collector. In order to introduce the beam between these surfaces and to shield the beam from any portion of the field outside of the field between these surfaces, the reentrant conducting members 23 and 24 of tubular form project inwardly of the resonator and are coaxial with the apertures 21' and 22' in the resonator and through which the beam is directed. These tubular conducting members 23 and 24 extend toward but are spaced from the surfaces of the re-entrant portions 21 and 22.

In operation a beam of electrons is directed from the cathode through the resonator 20 to the collector 19, the beam being subjected to the high frequency alternating electric field between the surfaces of the re-entrant portions 21 and 22, this field being substantially perpendicular to the beam at all times. This satisfies the condition set forth that the beam shall pass through the field of the resonator at right angles to the field so that pre-existing current density variations will not induce a voltage within the resonator. The resonator may be excited from an external source by means of a loop 20' coupled to the field within the resonator 20, the resonator being provided with an aperture through which the re-entrant portion 15' of the envelope extends to permit insertion of the coupling loop 20'.

In Figures 4 and 5 is shown a modification of the device shown in Figures 2 and 3 utilizing a different form of resonator and a slightly different form of collector and target electrode system.

As pointed out above, the purpose of the tubular members 23 and 24 in the resonator used in the devices shown in Figures 2 and 3 is to keep the electrons shielded from all but the most intense part of the electrical field within the cavity resonator. This is important, for best operation will occur when exposure to the field is no greater than one-half the resonant period. If the tubular members were omitted, control over the exposure time to the field would be lost or substantially so. The purpose of the construction of the resonator shown in Figures 4, 5 and 6 is to still retain the control while eliminating the tubular members,

which might under certain conditions adversely affect the oscillating fields within the resonator.

The envelope 25 has mounted within it a preferably indirectly heated cathode 26 and a collector 28. The cavity resonator 31 comprises essentially two hollow conducting bodies 32 and 33 having oppositely disposed spaced parallel sides or walls 32' and 33' provided with centrally positioned apertures 35' and 36'. Each of the portions 32 and 33 has a re-entrant portion 35 and 36 extended to and through the apertures 35' and 36' so as to provide oppositely disposed parallel surfaces between which a beam of electrons may be directed. A conducting collar 34 is coaxial with the apertures in the walls 32' and 33', and encloses the space between the apertures and provides a communicating passageway between the interiors of said hollow conducting bodies 32 and 33. The collar member 34 is provided with oppositely disposed apertures 37 and 38 which register with the space between the surfaces of the re-entrant portions 35 and 36. Thus the electron beam is shielded from the fields within the resonator except for the field between the opposed surfaces of the re-entrant portions 35 and 36. One of the hollow conducting bodies 32 or 33 may be provided with an aperture 33'' into which the re-entrant portion 25' of the envelope extends to permit the insertion of the coupling loop 31'. As shown the cathode 26 and collector 28 are mounted within the annular depression between the two halves of the resonator and close to the apertures 37 and 38. This arrangement permits shortening of the overall length of the beam, which lightens the focusing difficulties due to a long beam.

The various voltage sources for the cathode, and the resonator 31 are shown at 39, and 41, and the output circuit 42 is connected to the collector 28.

Another modification of my invention is shown in Figure 7. The envelope 45 has mounted at one end an indirectly heated cathode 46, a beam forming electrode 47 and at the other end a collector 48, a secondary emission suppressor electrode 49 and an apertured electrode 50 across which the beam may be deflected. Mounted within the envelope are a pair of truncated cone-shaped members 51 and 52, the truncated ends being opposite to each other and having surfaces lying in parallel planes. Surrounding these cone-shaped members is a hollow drum-shaped member comprising other cone-shaped elements 53 and 54 connected by means to a collar member 55 provided with oppositely disposed apertures 56 and 57 registering with the space between the surfaces of the cone-shaped members 52 and 51. These cone-shaped members are provided with leads and supports in the form of collars or rings 52', 51', 53' and 54' extending through the glass envelope. There may be mounted between the beam forming electrode 47 and the cone-shaped members 53 and 54 a tubular member 58 provided with an apertured partition 58', the aperture 58'' registering with the apertures 56 and 57 in the collar member 55. To complete the resonator I provide the hollow conducting bodies 59 and 60 formed by a surface of revolution of a geometric figure so as to provide extensions for the cone-shaped members 52, 54, 53 and 51, these members being provided with spring fingers such as 59', 59'', 60' and 60'' which engage the collar-like extensions 52', 54', 51' and 53', these hollow conducting members 59 and 60 being held in contact by means of bolts 61 and 62

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screwed into cup-shaped elements 65 and 66 secured to the members 52 and 51. With the members 59 and 60 removable, different sizes can be used for different frequencies.

It will be observed that in this form I have in effect provided a cavity resonator symmetrical about an axis passing through the bolt members 61 and 62, the re-entrant cone-like members providing surfaces between which the electric field is generated to deflect the electron beam. A coupling loop 70 may be inserted within the resonator to excite the same. The voltage sources are shown at 67, 68 and 69. The output circuit 71 is connected to the collector or anode 48. The interior of the hollow bodies may be silver plated to reduce surface resistance and losses due to this resistance.

In connection with the forms of resonator so far described and particularly with reference to the form of resonator utilized in Figures 4, 5 and 6, to facilitate the establishment of the proper dynamic state when only one-half of the resonator is excited, a modification may be provided. To illustrate the problem of excitation reference may be had to Figures 8 to 10, inclusive.

In Figure 10 is illustrated schematically two identical concentric line resonators back to back. They comprise the outer tubular member 75 and the inner conductors 76 and 77 closed at their ends at 78 and 79. The partition 80 separates the two resonators. If each resonator is now separately excited to produce the fields shown by the arrow lines, the partition plane 80 serves no purpose, for if it were removed, the E lines of the fields would join. It is, therefore, believed that having established such a state and having removed the partition, the excitation with one of the exciters removed would be maintained. It is this mode of operation which is necessary for the successful functioning of the device disclosed. On the other hand, suppose that the phase of one of the exciters is reversed. This situation is shown in Figure 8. Here the partition 80 is important and if removed the state illustrated in Figure 9 would result. It would be possible to maintain this form of excitation even with the partition removed.

The mode of operation illustrated in Figure 9 would not provide a field transverse to an electron beam passing through the center of the resonator in a plane transverse to the coaxial lines 75, 76 and 77. This mode would, therefore, be an undesired mode. This undesired mode will have a higher resonant frequency than the desired mode. If the higher resonant frequency is sufficiently removed from the frequency of the desired mode, so that it falls outside of the signal pass band, no problem is presented. If the higher frequency does not fall outside the signal pass band, the arrangement shown in Figure 11 illustrates a cure which makes the undesired mode non-existent; that is, the cavity will simply not resonate in the undesired mode.

If, therefore, difficulty should be experienced with some forms of device utilizing the cavity resonator shown in Figures 4, 5 and 6, the difficulty might be removed by utilizing the structure illustrated in Figure 11. The resonator 81 comprises the two hollow conducting bodies 82 and 83 and collar member 84 corresponding to the elements 32, 33 and 34 of Figure 6. To insure the type of operation desired and illustrated in Figure 10, coupling neck or conductor 85 could be extended between the two portions 82 and 83 to provide a communicating passageway so that the

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field formation will be that as shown in Figure 11, thus stabilizing the mode of operation desired. The undesired mode is non-existent in this form of resonator, that is, the resonator will not resonate in the undesired manner.

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 a cathode means for supplying a beam of electrons and a collector for said electrons and a cavity resonator positioned between said cathode means and collector and including a hollow conducting member provided with oppositely disposed apertures in opposite walls thereof through which the beam path extends, said resonator having oppositely disposed reentrant wall portions extending toward each other and providing surfaces within said cavity resonator lying in parallel planes positioned on opposite sides of and parallel to said beam path and between which an alternating electric field of high frequency is generated during operation of said device for periodically deflecting said beam, said resonator having means between each of said apertures and said oppositely disposed surfaces within said resonator for shielding said beam path.

2. An electron discharge device having a cathode means for supplying a beam of electrons and a collector for said electrons and a cavity resonator positioned between said cathode means and collector and including a hollow conducting member provided with oppositely disposed apertures in opposite walls thereof through which the beam path extends, said resonator having oppositely disposed surfaces extending from the inner walls of said resonator and toward each other and lying in parallel planes positioned on opposite sides of and parallel to said beam path between which an alternating electric field of high frequency is generated during operation of said device for periodically deflecting said beam, said resonator having means between each of said apertures and said oppositely disposed surfaces on the inner walls of said resonator to shield the beam path.

3. An electron discharge device having a cathode means for supplying a beam of electrons and a collector for said electrons and a cavity resonator positioned between said cathode means and collector and including a hollow conducting member having oppositely disposed apertures in opposite walls thereof through which the beam path extends, said resonator having oppositely disposed inwardly directed walls providing surfaces within said resonator lying in parallel planes and positioned on opposite sides of and parallel to said beam path between which an alternating electric field of high frequency is generated during operation of said device for periodically deflecting said beam, and tubular means extending from said apertures and between said apertures and said surfaces lying in parallel planes for shielding the beam path.

4. An electron discharge device having a cathode for supplying a beam of electrons and a col-

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lector for receiving said electrons, and a cavity resonator positioned between the cathode and the collector, said cavity resonator comprising a surface of revolution of a geometric figure, the walls of said resonator being re-entrant along the axis of the surface of revolution and extending toward each other and providing at their ends oppositely disposed parallel surfaces within said resonator, said resonator having oppositely dis-

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posed apertures registering with each other and with the space between the oppositely disposed parallel surfaces, the beam path extending through said apertures, and means between each of said apertures and said oppositely disposed parallel surfaces for shielding the path of the beam.

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