May 8, 1951 E. G. LINDER 2,552,334

ELECTRON DISCHARGE DEVICE AND ASSOCIATED CIRCUIT

Filed March 2, 1945 2 Sheets-Sheet 1

Fig. 1.

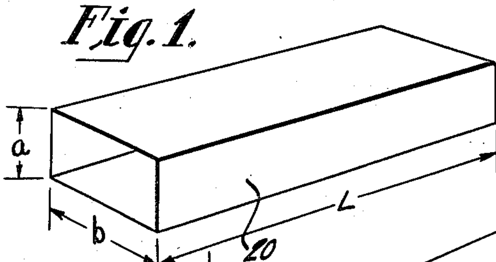

Fig. 2.

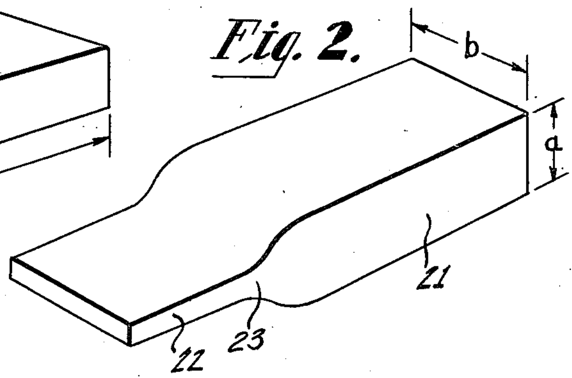

Fig. 3.

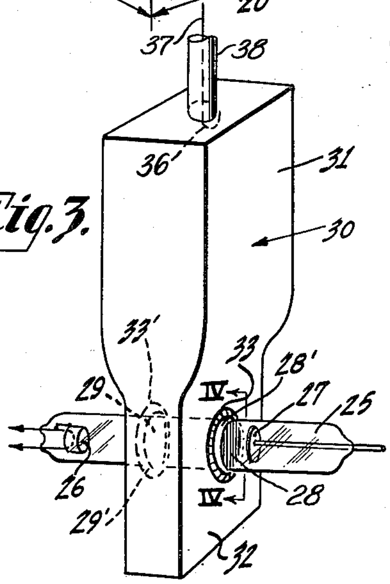

Fig. 4.

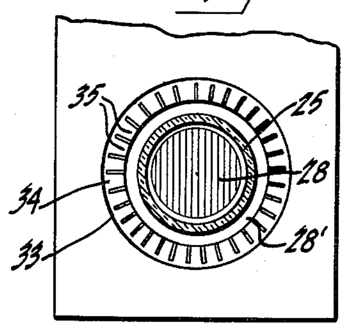

Fig. 5.

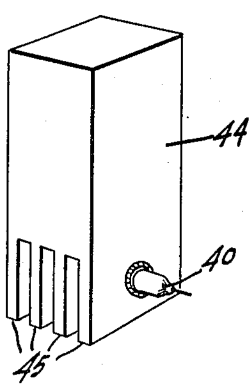

Fig. 6.

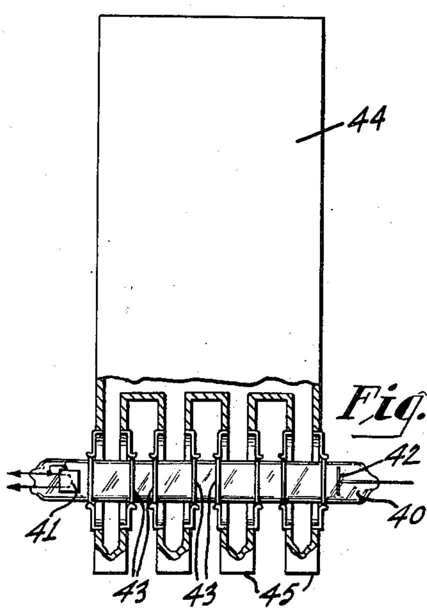

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Fig. 7.

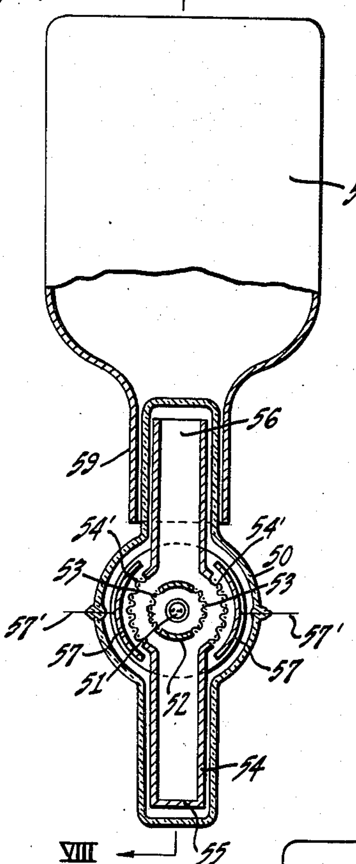


Fig. 8.

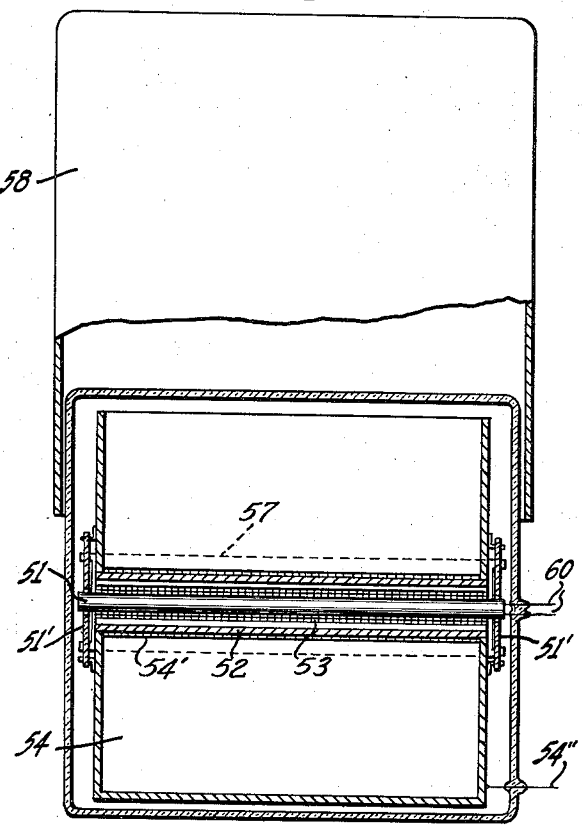


Fig. 9.

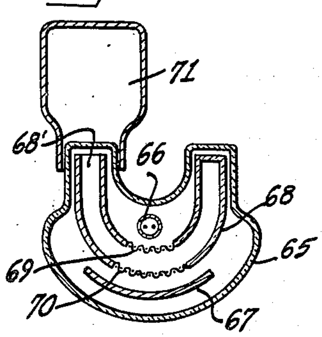


Fig. 10.

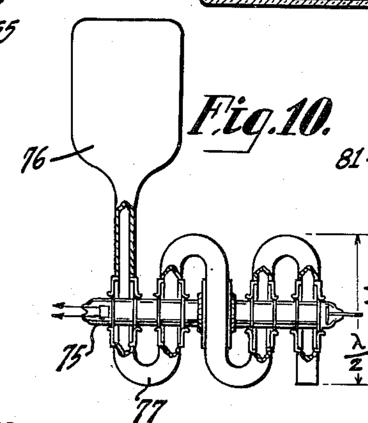
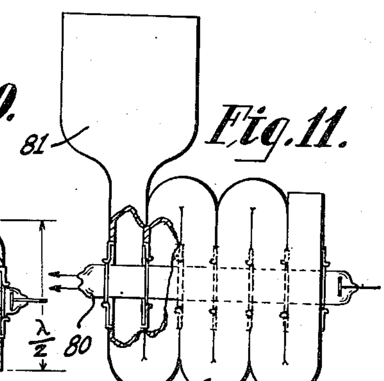


Fig. 11.



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Patented May 8, 1951 2,552,334

UNITED STATES PATENT OFFICE

2,552,334

ELECTRON DISCHARGE DEVICE AND ASSOCIATED CIRCUIT

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Application March 2, 1945, Serial No. 580,509

28 Claims. (Cl. 315—5)

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My invention relates to electron discharge devices and associated circuits, more particularly to such devices using cavity resonators.

In one form of ultra high frequency apparatus, an electron discharge device is associated with a cavity resonator circuit in such a manner that an electron beam is directed through the resonator either for control purposes or for the purpose of extracting energy from the electron stream by the resonator. This apparatus may include a resonator having oppositely disposed apertures in the walls of the resonator and through which an elongated electron discharge device extends so that the cathode is positioned on one side of the resonator with the collector or reflector on the other side of the resonator. Various arrangements have been utilized.

As the frequencies at which the apparatus is operated are increased, the dimensions of both the resonator and the electron discharge device must be decreased with the result that the electrode structures become increasingly smaller, limiting the power output of the apparatus and the ability to dissipate heat. Small electrode structures introduce manufacturing difficulties and to insure that the transit time of the electrons through the resonator falls within the limits required for operation at these high frequencies, it is necessary to use high accelerating voltages between the various electrodes. In order to limit the transit time of the electrons through the resonator, the portion of the resonator across which the beam is directed became increasingly constricted, thus introducing structural difficulties in the manufacture of the resonator.

It is, therefore, an object of my invention to provide an electron discharge device and associated circuit of the cavity resonator type of improved design.

A further object of my invention is to provide an electron discharge device and associated cavity resonator circuit which is useful at very high frequencies and yet in which a comparatively large electron discharge device may be used, thus permitting large electrodes and resulting dissipation of large amounts of power.

Another object of my invention is to provide apparatus of the type described, wherein low accelerating voltages are sufficient to provide the required transit time of the electrons through the cavity resonator even at very high frequencies.

A further object of my invention is to provide such an electron discharge device and associated cavity resonator which can be made of reasonable size, facilitating assembling and handling.

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A more specific object of my invention is to provide such an electron discharge device and associated cavity resonator in which the constricted portion through which the beam of electrons passes is not a limiting factor on the size of the resonator but which nevertheless permits the use of a large size cavity resonator which may be operated 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 drawing in which Figures 1 and 2 are perspective views of cavity resonators illustrating the principle of my invention, Figure 3 is an electron discharge device and associated cavity resonator circuit made according to my invention, Figure 4 is an enlarged section taken along the line IV—IV of Figure 3 and showing details of construction, Figure 5 is a perspective of a modified form of electron discharge device and associated circuit made according to my invention, Figure 6 is a side elevation of the apparatus shown in Figure 5 with parts in section showing details of construction, Figures 7 and 8 are end and side elevations with parts in section of a modified form of an electron discharge device and associated cavity resonator circuit made according to my invention, Figure 9 is a transverse section of a still further modification of an electron discharge device and associated cavity resonator circuit made according to my invention, and Figures 10 and 11 show further forms of an electron discharge device and associated cavity resonators made according to my invention.

It is known that in the case of waveguides, the wavelength of the propagated wave therein is frequently independent of one of the dimensions of the waveguide. Referring to Figure 1 for example, there is shown a rectangular guide having dimensions a, b and length L. When an $H_{0,1}$ wave with the electric field parallel to the dimension a along the minor transverse axis of the guide is transmitted through the waveguide from one end to the other along the dimension L it has been found that the dimension a may be varied without affecting the wavelength in the guide. The same holds true for $H_{0,2}$ wave, and also for higher orders.

This principle may be applied to closed cavity resonators which may be regarded as resonant sections of waveguides. For example, if the resonator of Figure 1 is a resonant section a wavelength long, we have

$$L=\lambda=\frac{\lambda_e}{\sqrt{1-\frac{\lambda_e^2}{4b^2}}}$$

where λ is the wavelength in the resonator and λ_e is the length of the wave in free space. It can be seen that the resonator wavelength is independent of the dimension a. Hence a may be varied at will to suit any special purpose.

A form of resonator particularly and peculiarly suitable for use in combination with an electron discharge device to provide a high frequency apparatus useful as an oscillator or as an amplifier is shown in Figure 2. Here the dimension a is made much smaller at one end 22 than at the other end 21, and calculations for wavelength by the above formula and wavelength measurements on actual construction show a very close agreement with each other. The Q of the resonator is very high. Preferably, the two resonator portions 21 and 22 are connected by a tapered transition portion 23 integral therewith, as shown, to avoid reflections in the resonator due to abrupt discontinuities in the walls thereof.

Apparatus made according to my invention is illustrated in Figures 3 and 4. In this arrangement an elongated electron discharge device or tube, having an envelope 25, an indirectly heated cathode 26 at one end, a collector or reflector 27 at the other end and intermediate grids 28 and 29 having grid contact and supporting rings 28′ and 29′ sealed through envelope 25, is used in combination with a cavity resonator 30 of the form shown in Figure 2. The lower end portion 32 of the resonator is a section of constricted transverse dimension in the direction of the path of the electron beam and the resonator is enlarged at the other end portion 31. The overall length of the resonator is preferably about one wavelength in the resonator, as in Figs 1 and 2, so that standing wave will be set up therein in the second harmonic mode of operation, considering the fundamental as the first harmonic. For optimum results, the beam should pass through the resonator at a voltage maximum of the standing-wave pattern therein. Hence, the discharge device is located along the resonator 30 at a distance of approximately a quarter-wavelength in the resonator from the closed end of the constricted portion 32. The lower end portion 32 is provided with a pair of oppositely disposed apertures 33 and 33′ through which the electron discharge device extends. The contact and supporting rings 28′ and 29′ provide electrical connection between the grids and inwardly-extending spring finger contacts such as 35 on a ring 34 mounted on the resonator walls. Thus the grids in effect form continuations of the resonator walls, providing a foraminous portion through which the electrons may be directed.

Since the size of the opening is not restricted in any way by the constricted portion of the resonator, large electrodes can be utilized and since the width of the resonator in the direction of the path of the electron beam can be made of any desired value, the transit time of the electrons through the resonator may be small even with very low voltages at very high frequencies.

A further advantage of the type of resonator utilized in Figure 3, of importance especially with very short waves, such as from 5 centimeters to .5 centimeter, is that this type of cavity resonator may be used as a wave magnifier. This is evident from the formula

$$\lambda=\frac{\lambda_e}{\sqrt{1-\frac{\lambda_e^2}{4b^2}}}$$

By varying the dimension b the cavity resonator wavelength may be changed all the way from λ_e to infinity, the latter value being attained when b is equal to

$$\frac{\lambda_e}{2}$$

Thus though a wave may be very short in free space, it may be long in a cavity resonator or waveguide. This is of importance since it offers a means of making large tubes to generate short waves, or to operate at high frequencies. By this means tubes having large elements may be used making use of large cathodes, plates, grids and the resultant dissipation of large power. This also permits constructional problems to be simplified.

Resonators of the type described are suitable for very short waves, for example, assuming $\lambda_e=1$ centimeter and $b=.6$ centimeter, then

$$\lambda=\frac{1}{\sqrt{1-\frac{1}{1.44}}}=1.8 \text{ centimeters}$$

This is several times larger than, for example, a toroidal resonator of the same length would be and permits the use of considerably more beam current.

High frequency energy may be introduced into the cavity resonator 30, or extracted therefrom, by any conventional means, such as a coupling loop 36, linked with the transverse magnetic component of the electromagnetic field within the resonator, forming a continuation of the central conductor of a coaxial transmission line 37, 38, as shown in Fig. 3.

In the modification shown in Figures 5 and 6, the electron discharge device is provided with an envelope 40 having at one end an indirectly heated cathode 41 and at the other a collector 42, a plurality of contact ring type grids 43 being spaced along the length of the tube. These grids may be of the form shown in Figures 3 and 4.

The cavity resonator 44 utilized in this arrangement is provided at its lower end with a plurality of restricted cavity resonator portions 45 instead of one as shown in Figure 3. The electric fields at any instant within the several restricted portions 45 will lie in the same direction parallel to the electron path. If the successive grids are equally spaced and the transit time of the electrons therethrough be suitably adjusted, each electron will be continuously accelerated or decelerated, depending on the time of entry into the resonator. This type of tube can be used for various purposes and it is of course understood that the transverse dimensions through the constricted portions 45 will be that required depending upon the use to which the apparatus is to be put. For example, if energy is to be extracted from the beam, the spacing between successive pairs of grids will be shorter as the electrons slow down, if operation requires this arrangement. On the other hand, if electrons are continuously accelerated then the spacing between the successive grids will be increased to take care of this provision. The device, of course, could be used as a reflex oscillator if a low positive or negative voltage were applied to the electrode 42 for directing electron groups back through the last of the constricted portions 45. Various other modifications readily suggest themselves.

In Figures 7 and 8 a still further modification of an apparatus made according to my invention is shown. In this arrangement I provide the electron discharge device with an envelope 50 in which is mounted an indirectly heated cylindrical cathode 51 surrounded by a tubular control electrode 52 having foraminous portions 53 through which the electrons are directed in oppositely disposed beams. This electrode 52 may be capacity coupled to the resonator 54, or directly connected thereto at the ends as shown in Fig. 8, depending upon whether or not it is desired to apply an alternating control voltage to the electrode 52. The resonator 54 in the form of a flat rectangular shaped resonator may be closed at one end 55 and open at its other end 56 and provided intermediate its ends with foraminous portions 54′ through which the electrons are directed toward two electrodes 57, which may be used as collectors or as reflectors, these electrodes being provided with leads 57′. The open end 56 of the resonator within the envelope 50 communicates with the interior of the enlarged portion of the resonator 58 through neck 59, which telescopes over the envelope and the open end of the resonator.

The cathode 51 is supported at its opposite ends from the resonator 54 within the envelope by means of insulating discs 51′, preferably of mica, and is provided with a pair of heater leads 60, one of which may be connected to the cathode to provide the cathode lead. The resonator may be provided with a lead 54″ upon which a high potential may be applied for biasing purposes with respect to the cathode and to which may also be applied an alternating voltage for modulating or controlling the passage of electrons through the resonator. The portion 58 of the resonator external of the envelope need not have any voltage applied thereto, thereby providing a safety feature.

Electrons may be accelerated and controlled in the space between the electrode 52 and cathode 51 and passed through the space between the foraminous sections of the resonator, either to excite the resonator or be reflected back through the resonator by electrodes 57 so that the whole apparatus functions as an oscillator.

Figure 9 shows a transverse section of another form of my invention in which the electron discharge device is provided with an envelope 65 and in which are mounted an indirectly heated cathode 66 and an oppositely disposed collector or reflector 67, electrons from the cathode to the collector passing through an arcuate shaped constricted resonator 68 at foraminous portions 69 and 70. The open end 68′ of the resonator 68 communicates with the interior of an enlarged resonator 71 in the manner shown in Figures 7 and 8.

Another form of multiple action apparatus is shown in Figure 10 and a further modification in Figure 11, in which the constricted portion 77 of the resonator through which tube 75 extends is folded. In the arrangement shown in Figure 10, the distance between folds 77 is preferably equal to the thickness of the cavity and hence the electrons travelling with constant velocity through the grids or apertures will spend equal time inside and outside the folds. The length of each fold is equal to

$$\frac{\lambda}{2}$$

hence the electric fields at any instant inside all the folds at the apertures will lie in the same direction parallel to the electron path, and the fields between the folds will lie in the opposite direction. By adjusting the speed of the electrons, alternate half periods will be spent inside the resonator and the field seen by each electron will always be in the same direction so that electrons would always be accelerated or decelerated, depending upon the time of entry of the electrons into the initial portion 76 of the resonator. The enlarged portion of the resonator communicates with the restricted portion as shown.

A similar effect would be obtained by the arrangement shown in Figure 11. Folding is again employed here but the folds are in contact with each other so that only the thickness of the metal separates adjacent interior sections. In this case the cavity resonator is operated near cut-off so that $\lambda >> \lambda_e$. As a consequence the field in the entire folded section is in the same phase. However, adjacent sections will have reversed field directions at any instant due to folding. Thus electrons travelling at such speed as to require a half period to pass through each fold will be continuously accelerated or decelerated. This applies to devices employing small degrees of oscillation, such as detectors and converters.

It is of course obvious that the resonators could be used as part of the tube envelope.

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 for supplying a stream of electrons along a given path, an electrode spaced from said cathode and positioned in said path toward which electrons are directed during operation of said device, and an elongated cavity resonator closed at both ends and having a predetermined resonant frequency and positioned between said cathode and said electrode and through which said electron path lies, said cavity resonator comprising an elongated hollow conducting member of substantially uniform transverse dimension therethrough normal to said path and haping an overall length of approximately one wavelength in the resonator of the operating frequency of said device and having at one end thereof a section of constricted transverse dimension normal to said uniform transverse dimension, said electron path extending through said section in a direction parallel to said constricted transverse dimension.

2. An electron discharge device having a cathode for supplying a stream of electrons along a given path and an electrode in said path to-

ward which said electrons are directed during operation of said device, and an elongated cavity resonator closed at both ends and having a predetermined resonant frequency and positioned between said cathode and said electrode and through which said path lies, the longitudinal axis of said resonator being normal to the path of the electron stream, said resonator being of substantially uniform transverse dimension normal to said electron path and having two communicating portions of substantially different transverse dimension parallel to said electron path, the electron path passing through the portion of smaller transverse dimension.

3. An electron discharge device according to claim 2, wherein said two communicating resonator portions are connected by a tapered portion integral therewith.

4. An electron discharge device having a cathode for supplying a stream of electrons along a given path, an electrode in said path spaced from said cathode and toward which said electrons are directed during operation of said device, and an elongated cavity resonator positioned between said cathode and said electrode and through which said path lies, said resonator having an overall length of approximately one wavelength in the resonator of the operating frequency of said device and comprising two communicating portions of substantially different transverse dimension parallel to said path, said passing through the portion of smaller transverse dimension.

5. An electron discharge device according to claim 4, wherein said two communicating portions are connected by a tapered portion integral therewith.

6. An electron discharge device having a cathode for supplying a stream of electrons along a given path and an electrode in said path spaced from said cathode and towards which said electrons are directed during operation of said device, and an elongated cavity resonator closed at both ends and having a predetermined resonant frequency and positioned between said cathode and said electrode and through which said path lies, said resonator comprising a first portion of given transverse dimension in one direction, a second portion of substantially greater uniform transverse dimension in said direction and a third portion whose transverse dimensions in said direction at the ends thereof are equal to said first and second portions, respectively, connected between said portions, said first portion having apertures in opposite walls thereof through which said path extends in said direction.

7. A cavity resonator of predetermined resonant frequency for use with a high frequency electron discharge device, comprising an elongated hollow conducting member of substantially uniform transverse dimension in one direction, said member being closed at both ends and having two communicating portions of substantially different transverse dimension normal to said uniform transverse direction, opposite walls of the portion of smaller transverse dimension being apertured to permit passage of an electron beam therethrough.

8. A cavity resonator of predetermined resonant frequency for use with a high frequency electron discharge device, comprising an elongated hollow conducting member closed at both ends and having at one end a plurality of parallel portions of restricted transverse dimension, the walls of said restricted portions being provided with registering apertures to permit passage of an electron beam therethrough.

9. A cavity resonator of predetermined resonant frequency for use with a high frequency electron discharge device, comprising an elongated hollow conducting member closed at both ends and having a folded portion of restricted transverse dimension, the walls of said folded portion being provided with registering apertures to permit passage of an electron beam therethrough.

10. A cavity resonator according to claim 7, wherein the transverse section of said elongated hollow conducting member throughout the length thereof is rectangular in form with said uniform transverse dimension lying parallel to the major axis of the rectangle.

11. A cavity resonator according to claim 7, wherein the overall length of the resonator is approximately one wave-length in the resonator of the operating frequency thereof.

12. A cavity resonator of predetermined resonant frequency for use with a high frequency electron discharge device comprising an elongated hollow conducting member closed at both ends and having a first portion of given uniform transverse dimension throughout in one direction, a second portion of substantially greater uniform transverse dimension throughout in said direction, and a tapered portion connected at its ends to said first and second portions, opposite walls of said first portion being apertured to permit passage of an electron beam therethrough.

13. An electron discharge device having a cathode for supplying electrons along a given path, and an electrode in said path toward which said electrons are directed during operation of said device, and an elongated cavity resonator closed at both ends and having a predetermined resonant frequency and positioned between said cathode and said electrode and through which said path lies, the longitudinal axis of said resonator being normal to said path, said resonator having rectangular transverse cross sections at different positions along the length thereof parallel to said electron path, the transverse cross section of the portion of said resonator through which said electron path lies having a dimension parallel to said electron path smaller than the corresponding dimension of other portions of said resonator.

14. An electron discharge device having a cathode for supplying electrons along a given path and an electrode in said path toward which said electrons are directed during operation of said device, a pair of spaced electrodes positioned between said cathode and said electrode in said path, and an elongated cavity resonator closed at both ends and having a predetermined resonant frequency and extending transversely of the electron path, opposite walls at one end thereof having apertures therethrough, said spaced electrodes registering with said apertures and connected to the walls of said resonator, said resonator being of substantially uniform transverse dimension normal to said electron path and having a smaller transverse dimension parallel to the electron path at said apertures than other portions of said resonator.

15. In combination an electron discharge device having an elongated envelope and having a cathode at one end thereof for supplying electrons along a given path, and another electrode in said path at the other end toward which said

electrons are directed during operation of said device, a pair of spaced grid members positioned between said cathode and said electrode and lying in said path and having radially directed contacts and supports extending through the wall of said envelope, and an elongated cavity resonator closed at both ends and having a predetermined resonant frequency and extending transversely of the electron path and being of substantially uniform transverse dimension normal to said electron path and having a portion of restricted transverse dimension parallel to said path at one end and provided at said restricted portion with a pair of oppositely disposed apertures through which said electron discharge device extends, said contacts and supports of said spaced grids being connected to opposite walls of said resonator.

16. An electron discharge device having a cathode for supplying electrons along a given path and an electrode in said path toward which said electrons are directed during operation of said device, and an elongated cavity resonator closed at both ends and having a predetermined resonant frequency and positioned between said cathode and said electrode and through which the electron path is directed, said cavity resonator having at one end thereof a plurality of spaced portions of constricted transverse dimension parallel to said path, said electron path being directed through said spaced constricted portions.

17. In combination, an electron discharge device having an elongated envelope, a cathode at one end of the envelope for supplying electrons along a given path, an electrode in said path at the other end of the envelope toward which said electrons are directed during operation of said device, and a plurality of transverse grid members positioned successively along said envelope in said path and having contacts extending through the walls of the envelope, and an elongated cavity resonator closed at both ends and having a predetermined resonant frequency and including an elongated hollow conducting member provided at one end with a plurality of portions of constricted transverse dimension parallel to said path, said constricted portions having registering apertures through which said electron discharge device extends, the grid contacts being electrically connected to the walls of said constricted portions at said apertures.

18. An electron discharge device having a cathode for supplying electrons along a given path and an electrode in said path toward which said electrons are directed during operation of said device, and a cavity resonator positioned between said cathode and said electrode and having an enlarged portion and a curved portion of restricted transverse dimension, said restricted portion being provided with oppositely disposed foraminous sections disposed in said path and through which the electrons may be directed toward said electrode during operation of said device, said restricted portion communicating with said enlarged portion.

19. An electron discharge device having an envelope containing a cathode for supplying electrons along a given path and an electrode in said path toward which said electrons are directed during operation of said device, and a first cavity resonator section positioned between said cathode and said electrode and comprising a curved portion of restricted transverse dimension, said restricted portion being provided with oppositely disposed foraminous sections disposed in said path and through which the electrons may be directed toward said electrode during operation of said device, and a second cavity resonator section having an enlarged portion having a transverse dimension larger than that of said restricted portion and positioned externally of said envelope, said cavity resonator sections having open ends communicating with each other.

20. An electron discharge device having an envelope, a cathode within said envelope for supplying electrons along a given path, and an electrode in said path toward which said electrons are directed during operation of said device, a first cavity resonator section positioned within said envelope and between said cathode and said electrode, said first resonator section being U-shaped and provided intermediate the ends of the U with foraminous portions disposed in said path and through which electrons are directed toward said electrodes during operation of said device, the end of one leg of said U being closed and the other open, and a second cavity resonator section outside said envelope and having a larger transverse section than that of said U-shaped section and coupled with the open leg of the first resonator section within said envelope to provide a resonator having restricted and enlarged portions.

21. An electron discharge device having an envelope, a cathode within said envelope for supplying electrons along a given path, and an electrode in said path toward which said electrons are directed during operation of said device, a first cavity resonator section positioned within said envelope and between said cathode and said electrode, said first resonator section being U-shaped and provided intermediate the ends of the U with foraminous portions disposed in said path and through which electrons are directed toward said electrode during operation of said device, the end of one leg of said U being closed and the other open, and a second cavity resonator section outside said envelope and coupled with the open leg of the first resonator section within said envelope to provide a resonator.

22. An electron discharge device having a cathode for supplying electrons along a given path and an electrode in said path toward which said electrons are directed during operation of said device, and a cavity resonator closed at both ends and having a predetermined resonant frequency and positioned between said cathode and said electrode and having a folded portion of restricted transverse dimension through which said path lies and a portion communicating with said folded portion having a corresponding transverse dimension greater than said transverse dimension of the folded portion.

23. An electron discharge device having a cathode for supplying electrons along a given path and an electrode in said path toward which said electrons are directed during operation of said device, and a cavity resonator closed at both ends and having a predetermined resonant frequency and positioned between said cathode and said electrode and having a folded portion of restricted transverse dimension through which said path lies and a portion communicating with said folded portion having a transverse dimension greater than the transverse dimension of the folded portion, adjacent folds being spaced from each other a distance equal to the distance travelled by an electron during a half period of the operating frequency of said resonator.

24. An electron discharge device having a cathode for supplying electrons along a given path and an electrode in said path toward which said electrons are directed during operation of said device, and a cavity resonator closed at both ends and having a predetermined resonant frequency and positioned between said cathode and said electrode and having a folded portion of restricted transverse dimension through which said path lies and a portion communicating with said folded portion having a transverse dimension greater than the transverse dimension of the folded portion, said folds being adjacent each other with no spacing between.

25. An elongated resonator having at one end a portion of restricted transverse dimension, a cathode for supplying electrons along a given path positioned within said restricted portion and surrounded by a conducting member forming part of the wall of said resonator and provided with a foraminous section in said path through which electrons may be directed during operation of said device, another part of said wall registering with the first mentioned part and provided with a foraminous section through which said beam path lies, and an electrode in said path toward which said electrons are directed after passing through said foraminous sections during operation of said device.

26. An electron discharge device having an envelope containing a cathode for supplying electrons along a given path, a cavity resonator section surrounding said cathode within said envelope, said resonator section having an inner conducting wall surrounding said cathode and provided with a first foraminous portion in said path through which electrons may be directed during operation of said device, said resonator section having an outer wall provided with a second foraminous portion through which said path lies, an electrode positioned in said path outside of said resonator section and toward which said electrons are directed during operation of said device, said resonator section being open along a portion thereof, and a cavity resonator section outside said envelope and communicating with the section inside said envelope, the section outside of said envelope having a transverse dimension larger than the corresponding transverse dimension of the section within said envelope.

27. An electron discharge device having an envelope and containing a cathode, a cavity resonator surrounding said cathode and having an inner wall surrounding said cathode, said inner wall being provided with a pair of oppositely disposed foraminous portions, said resonator having an outer wall enlarged adjacent said cathode and provided with a pair of foraminous portions registering with the cathode and the foraminous portions of said inner wall, and a pair of electrodes on the outside of said resonator and registering with said foraminous portions and toward which electrons from said cathode are directed during operation of said device, said resonator being open along one portion thereof, and a cavity resonator external of said envelope and having a portion telescoped over said envelope and over the open portion of said resonator within said envolep whereby the interior of the inner and outer resonators electrically communicate with each other, the resonator external of said envelope having a portion of transverse dimension greater than the corresponding dimension of the resonator within said envelope.

28. An electron discharge device having a cathode for supplying electrons along a given path and an electrode in said path toward which said electrons are directed during operation of said device, and an elongated cavity resonator closed at both ends and having a predetermined resonant frequency, the transverse dimensions of said resonator being uniform throughout the length thereof, one end of said resonator being divided into a plurality of spaced portions of small thickness compared to said transverse dimensions opening into the remainder of said resonator, said beam path extending through said spaced portions.

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