March 4, 1947. J. R. PIERCE 2,416,714

ELECTRON DISCHARGE DEVICE

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FIG. 1

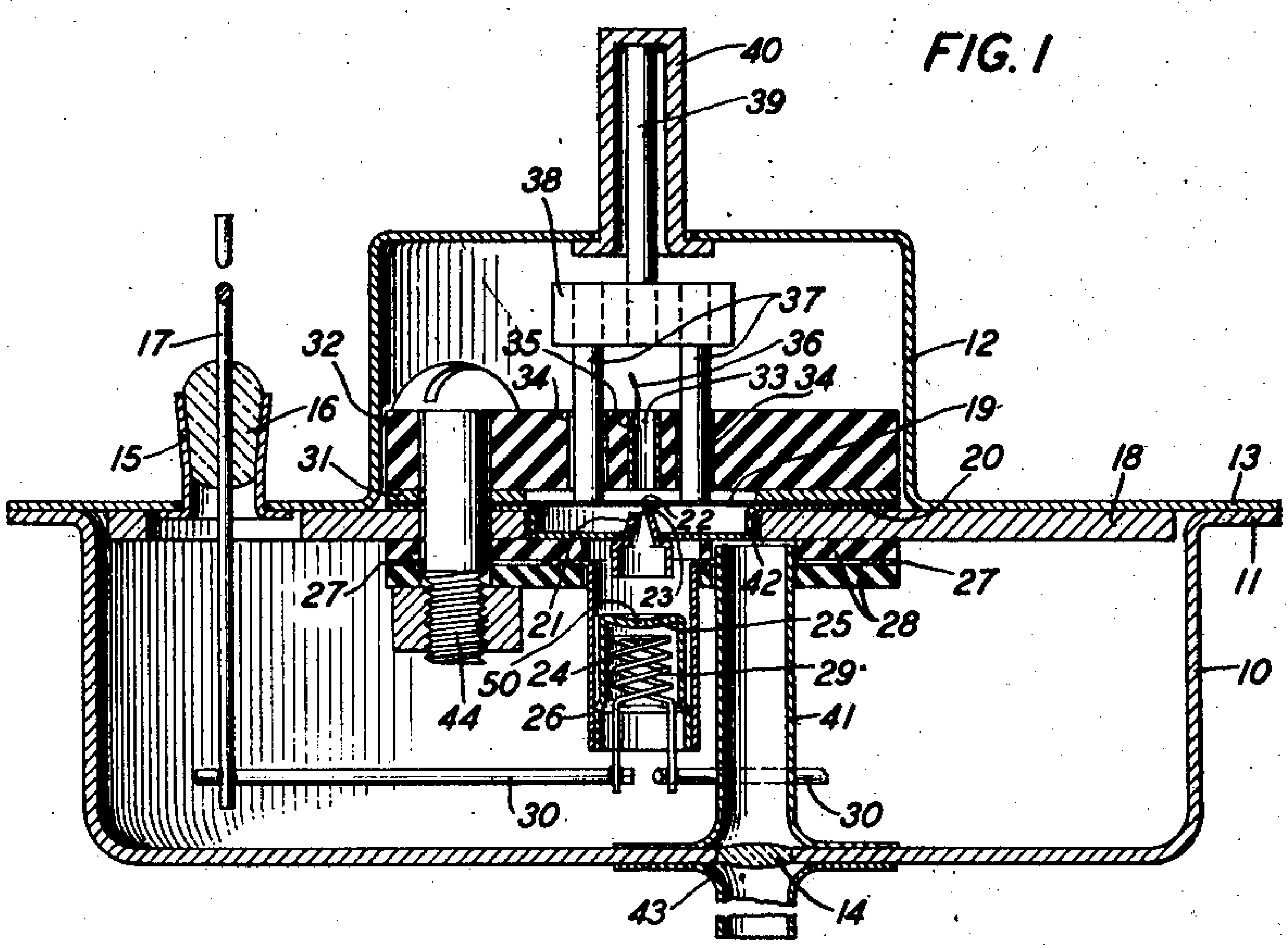
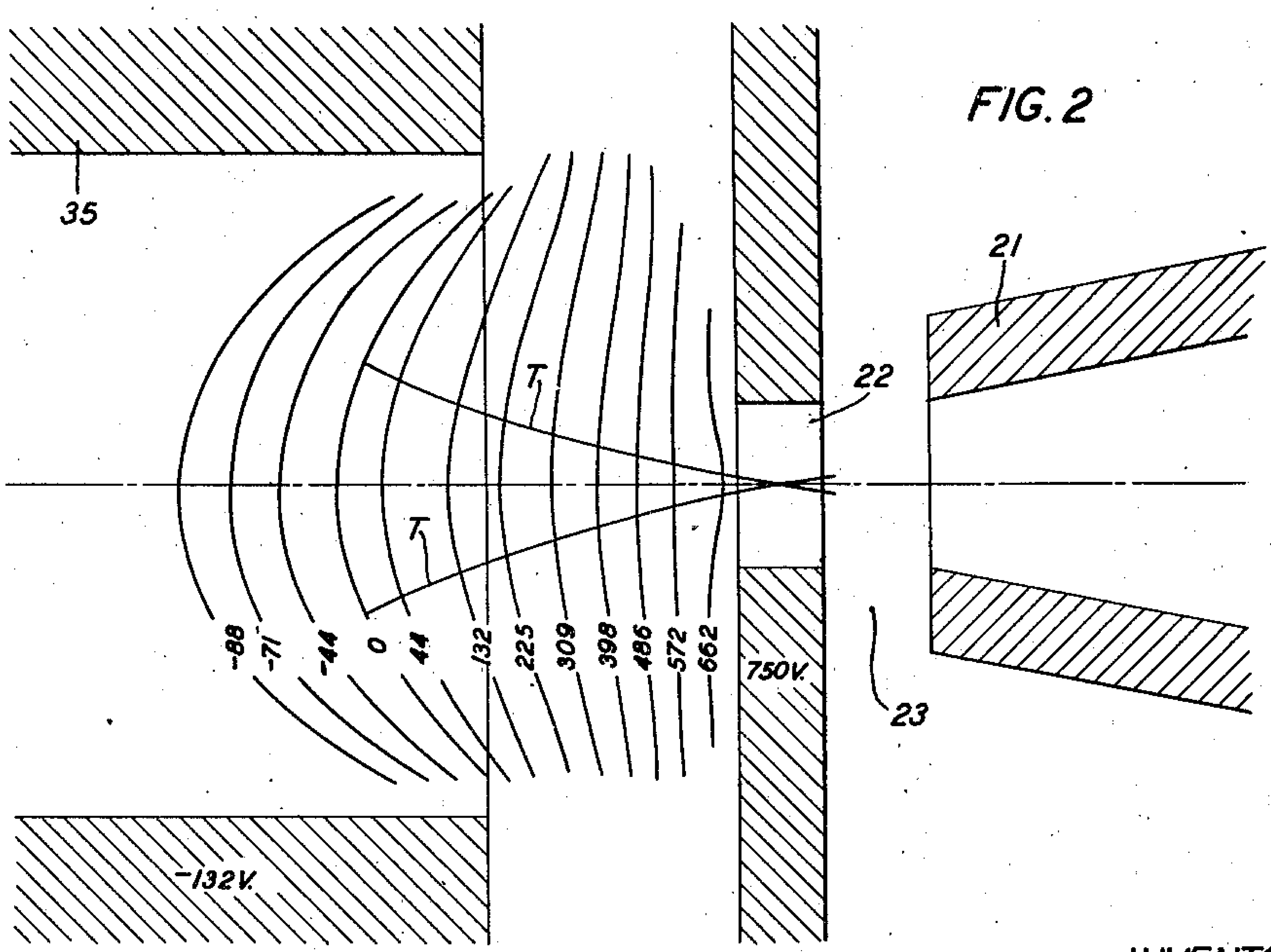


FIG. 2



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ELECTRON DISCHARGE DEVICE

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This invention relates to electron discharge devices and more particularly to velocity variation oscillators of the reflection type and operable at extremely high frequencies, for example frequencies corresponding to wave-lengths of the order of one centimeter.

Velocity variation oscillators of the reflection type comprise, in general, a cavity resonator having a gap therein, an electron gun for projecting a stream of electrons across this gap whereby the stream is velocity varied in accordance with the radio frequency field extant in the resonator, and a reflecting or repeller electrode effective to reverse the direction of motion of the electrons in a region beyond the gap, in which region the velocity variations are converted into density variations by drift space action, the reversed electrons being again projected into the gap in proper phase to contribute energy to the radio frequency field and thus to sustain oscillations.

The frequency of the oscillations generated depends upon the transit time of the forwardly projected electrons across the gap and, in general, the higher the frequency desired the shorter the transit time required. Also, in general, the higher the frequency desired, the smaller the physical parameters of the resonator and electrodes must be. In any oscillator of this type, the operating efficiency and other characteristics are dependent largely upon the magnitude of the forwardly projected electron current crossing the gap in proportion to the total forwardly projected electron current and the magnitude of the current projected into the gap in the reverse direction. The attainment of desirable operating characteristics in devices wherein the elements are of the small dimensions requisite for microwave operation entails sharp focusing of both the forwardly projected and reversed electron streams upon the gap and this in turn necessitates the extremely accurate location of the electron gun and repeller electrode with respect to the gap and the maintenance of such location during the operation of the device.

Furthermore, in reflection type velocity variation oscillators the character of the electric field in the region wherein the reversal of electron motion and the drift action occurs is largely determinative of the electronic conductance which can be realized and of the range of frequencies throughout which the device can be tuned electronically, that is by varying the potential of the reflecting or repeller electrode.

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One object of this invention is to enable and to facilitate the attainment and maintenance of extremely accurate location of the electron gun and repeller electrode with respect to the cavity resonator gap in velocity variation oscillators of the reflection type.

Another object of this invention is to realize in the drift space region of a reflection type velocity variation oscillator a non-uniform electric field of such character as to sharply focus the reflected electrons upon the gap and to assure a strong drift action.

In accordance with one feature of this invention, the cavity resonator, electron gun and reflecting or repeller electrode are fabricated as a rigid unitary assembly and are of such construction that they can be coaxially aligned readily, both mechanically and optically, with great accuracy during the fabrication of the unitary assembly.

In accordance with another feature of this invention, the repeller electrode is made in the form of an open-ended cylindrical tube which acts as a converging electron optical mirror effective to focus the reflected electron stream upon the gap in the cavity resonator.

In accordance with a further feature of this invention, the repeller electrode and cavity resonator are so constructed and arranged that the field in which the drift action occurs decreases in intensity toward the zero equipotential region thereof whereby a strong drift action and a relatively large change in electron transit time through the drift space with relatively small change in the energy of an electron projected into this space are obtained.

The invention and the above-noted and other features thereof will be understood more clearly and fully from the following detailed description with reference to the accompanying drawing, in which:

Fig. 1 is an elevational view in section of a velocity variation reflection type oscillator illustrative of one embodiment of this invention; and

Fig. 2 is a diagram, to a greatly enlarged scale, of a portion of the oscillator illustrated in Fig. 1 showing the field between the cavity resonator and the repeller electrode and typical electron paths in this field.

Referring now to the drawing, the electron discharge device illustrated in Fig. 1 comprises an evacuated enclosing vessel having a cup-shaped base portion 10 provided with a flange 11 and a cup-shaped top portion 12 provided with a flange 13. The portions 10 and 11 may be of metal and are joined hermetically to each other as by welding the flanges 11 and 13 together. The base wall of the portion 10 is provided with an aperture in which a vitreous disc 14 is sealed hermetically. Alternatively, the disc 14 may be sealed within the member 41 described hereinafter. The flange 13 is provided with a plurality of apertures, only one of which is shown, into each of which an eyelet 15 extends, each eyelet being welded hermetically to the flange and having sealed thereto a vitreous bead 16 in which a leading-in conductor 17 is sealed.

Mounted within the vessel 10, 12 is a unitary assembly which comprises an annular foundation plate 18 secured to the flange 13 as by welding, and an annular cavity resonator 19 disposed in the opening in the foundation plate 18 and provided with an annular flange 20 seated on the plate. The resonant cavity is bounded in part by a hollow member having a frusto-conical portion 21 which is secured to the resonator 19 and is axially aligned with an aperture 22 in one wall of the resonator, the smaller end of the member 21 and the wall portion in juxtaposition thereto defining a short gap 23. The resonator 19 and frusto-conical member 21 are fabricated conveniently of copper or copper plated steel and the member 21 is joined, as by soldering or welding, to the resonator while being held in accurate alignment with the aperture 22 by a suitable aligning tool inserted through the aperture 22 and member 21.

Axially aligned with the resonator and the gap 23 therein is an electrode assembly which includes a tubular cathode 24 having a dished end portion 25 provided with a central aperture 50 and the concave surface of which is coated with a thermionic material, and a tubular beam-forming electrode 26 joined to the cathode and provided with a flange 27 which extends between a pair of insulating discs 28. A heater filament 29 is supported within the cathode by conductors 30 secured to respective leading-in conductors 17. The cathode, beam-forming electrode 26 and frusto-conical member 21 constitute an axially symmetrical electron gun for producing a concentrated electron stream converging toward and focused to a point upon the gap 23.

Seated upon the foundation plate 18 is an annular metallic washer 31 upon which there is seated in turn an insulating, for example ceramic, block or plate 32 having a central aperture 33 in axial alignment with the gap 23 and having also other apertures 34. The bounding surface of the central aperture 33 is coated with an electrically conductive material, such as silver, to form a tubular reflecting electrode 35 to which electrical connection may be established by way of a leading-in conductor 36 secured thereto and connected to an appropriate leading-in conductor, not shown, extending from the enclosing vessel through an eyelet seal similar to that shown at 15, 16.

Extending through the apertures 34 are rigid posts or rods 37 which are secured at one end to the wall of the resonator 19 opposite the insulating member 32 and are joined at the other end to a rigid bridge piece 38 which is carried by another rigid post or rod 39 joined to a sleeve 40 which is sealed hermetically to the portion 12 of the enclosing vessel. The resonator wall mentioned and the base wall of the portion 12 are flexible so that the linkage composed of the posts 37 and 39 and bridge piece 38 can be moved longitudinally by suitable means external to the vessel 10, 12 to flex the wall of the resonator and thus adjust the resonant frequency of the resonant cavity. Energy may be taken from the cavity by way of a wave guide 41, which may be, for example, substantially a narrow rectangle in cross-section, secured to the base wall of the vessel portion 10 in alignment with the disc 14 and communicating with the cavity through a slit 42 bounded in part by a portion of the resonator 19 and in part by the plate 18. A similar external wave guide 43 may be joined to the base wall of the vessel portion 10 in alignment with the internal guide 41.

In the manufacture of the device, the plate 18, resonator 19, electrode assembly 24, 26, insulating disc 32 and the associated washers 28 and 31 are fabricated as a unitary assembly in which all of the electrodes and the resonator are axially aligned with great accuracy and are firmly maintained in this aligned relation. Specifically, both the electrode assembly 24, 26 and the block or disc 32 are positioned in axial alignment with the aperture 22 and member 21 by a suitable aligning tool projecting through the aperture 50, member 21, aperture 22 and repeller electrode 35, and the parts constituting the unitary assembly are clamped firmly together by a plurality of bolts 44, only one of which is shown. The alignment of the parts after assembly thereof can be checked optically by viewing through the apertures 22 and 50, member 21 and electrode 35. This assembly, with the tuning linkage in place, is then mounted upon the vessel portion 12 by welding the plate 18 to the flange 13 and the post or rod 39 is sealed to the sleeve 40. Subsequently, the heater filament 29 is mounted in place and the flanges 11 and 13 are joined hermetically.

The importance of the feature of the construction which enables fabrication of the electrodes and resonator as a unitary assembly wherein the elements noted are aligned with great accuracy will be appreciated especially from a consideration of typical dimensions in a device of the construction illustrated in Fig. 1 and adapted for operation at the order of 1 centimeter wavelength. The aperture 22 is substantially 0.01 inch in diameter, the repeller electrode is substantially 0.06 inch in internal diameter and the cathode 24 is substantially 0.125 inch in diameter. Obviously, a misalignment of either the cathode 25 or repeller electrode 35 with the gap 23 measured in thousandths of an inch will greatly reduce the operating efficiency and materially affect the operating characteristics of the device inasmuch as any misalignment reduces either the electron current which is projected into the gap 23 by the electron gun or the reflected electron current projected into the gap 23 from the repeller electrode, or both.

In the operation of the device, the cavity resonator 19 is maintained at a high positive potential with respect to the cathode and the repeller electrode is maintained at a negative potential. For example in a typical device, the resonator may be operated at 750 volts positive and the repeller electrode 132 volts negative with respect to the cathode. Electrons from the cathode are projected into the gap 23 where they are velocity varied by the field within the resonator and then into the region between the aperture 22 and the repeller electrode. Here the electrons undergo a drift space action and reversal in direction of motion and the velocity variations are converted into density variations. The density varied stream then is projected into the gap **23** in proper phase to contribute energy to the field within the resonator and thus sustain oscillations.

The character of the field in the region in which the drift action occurs is of prime importance in the determination of the operating characteristics of the device in that it has an important effect upon the magnitude of the drift action and the electronic conductance obtained thereby determines the degree of focusing of the reversed electrons upon the gap **23** and also the frequency range throughout which the device can be tuned electronically, i. e., by varying the potential of the repeller electrode **35**. The tubular repeller electrode **35** constructed in accordance with a feature of this invention enables realization, in the space in which the drift action occurs, of fields which result in a high degree of conversion, sharp focusing of the electrons and a relatively wide electronic tuning range.

In Fig. 2 the curved numbered lines indicate the equipotential lines in the drift space in a device wherein the aperture **22** and repeller electrode **35** are of the dimensions given heretofore, the space between the juxtaposed resonator wall and repeller electrode end being substantially 0.015 inch and the resonator and repeller electrode voltages being as shown. The numeral associated with each equipotential line represents the potential of that line.

It will be noted from Fig. 2 that the form of the field is such that electrons therein are focused upon a point within the aperture **22**, the repeller electrode constituting a convergent electron optical mirror. Typical electron trajectories are represented by the lines T. Although, as indicated in the figure, the electron path crosses the axis of the system slightly before, i. e., to the left of, the gap **23**, this is not objectionable, but on the contrary is advantageous in that the over convergence compensates for divergence of the electron stream due to space charge, so that a high percentage of the electrons projected into the drift space are returned to the gap **23**.

It will be noted further that the field decreases in intensity toward the zero equipotential region. Consequently, a small change in electron energy due to radio frequency voltage across the gap **23** will result in a relatively large change in the distance of travel of an electron from the gap, into the field and back again into the gap and, hence, a correspondingly large change in the transit angle of an electron through the drift space. This results in a wide electron tuning range. Furthermore, a strong drift action is realized and a high negative electron conductance is obtained.

Although a specific embodiment of this invention has been illustrated and described, it will be understood that it is but illustrative and that various modifications may be made therein without departing from the scope and spirit of this invention as defined in the appended claims.

What is claimed is:

1. An electron discharge device comprising an enclosing vessel and a unitary assembly within said vessel, said assembly comprising a foundation member, a cavity resonator having opposed wall portions provided with aligned restricted apertures, an electron gun opposite one of said wall portions and axially aligned with said apertures, a repeller electrode opposite the other of said wall portions and axially aligned with said apertures, and means separate from said vessel fixedly securing said resonator, gun and repeller electrode to said foundation member.

2. An electron discharge device comprising an enclosing vessel and a unitary assembly within said vessel, said assembly comprising a foundation member having an aperture therein, a cavity resonator within said aperture and having opposed wall portions provided with aligned restricted apertures, an electron gun opposite one of said wall portions and axially aligned with said restricted apertures, a repeller electrode opposite the other of said wall portions and axially aligned with said restricted apertures, and means separate from said vessel clamping said member, resonator, gun and electrode together.

3. An electron discharge device comprising a unitary assembly comprising a foundation plate having an aperture therein, a cavity resonator within said aperture and having opposed wall portions provided with aligned restricted apertures, said resonator having also a flange seated on said plate, a repeller electrode assembly opposite one of said wall portions seated on said flange and having a hollow conductive portion in alignment with said restricted apertures, an electron gun opposite the other of said wall portions and in alignment with said restricted apertures, and means securing said resonator, repeller electrode assembly and gun to said plate.

4. An electron discharge device comprising an enclosing vessel and a unitary assembly within said vessel, said assembly comprising a foundation plate having an aperture therein, a cavity resonator within said aperture and having opposed wall portions provided with restricted apertures, a repeller electrode opposite one of said wall portions and having an opening therein in alignment with said restricted apertures, an electron gun opposite the other of said wall portions and including a member having an opening therein in alignment with said restricted apertures, and means independent of said vessel securing said resonator, electrode and gun to said foundation plate.

5. An electron discharge device comprising a unitary assembly comprising a foundation plate having an aperture therein, a cavity resonator within said aperture and having a supporting portion seated on said plate, said resonator including opposed wall portions provided with aligned restricted apertures, a tubular repeller electrode opposite one of said wall portions and in alignment with said restricted apertures, support means for said repeller electrode, an electron gun opposite the other of said wall portions and including a member having therein an aperture in alignment with said restricted apertures, support means for said gun, and means clamping said supporting portion and said electrode and gun support means to said foundation plate.

6. An electron discharge device comprising a unitary assembly comprising a foundation plate having an aperture therein, a cavity resonator having a flange seated upon one face of said plate and having also opposed wall portions provided with aligned restricted apertures, a tubular repeller electrode opposite one of said wall portions and in alignment with said restricted apertures, support means for said electrode seated upon said flange, an electron gun opposite the other of said wall portions and including a cathode having therein an opening in alignment with said restricted apertures, support means for said gun including a member abutting the other face of said plate, and means clamping said flange

and said electrode and gun support means to said plate.

7. A velocity variation reflection type oscillator comprising a cavity resonator having a gap therein, means opposite said gap for projecting an electron stream thereacross, and means for reversing the direction of said stream after it has crossed said gap and again projecting it into said gap, said second means comprising an open-ended, cylindrical repeller electrode defining an electron optical mirror having its focus substantially at said gap.

8. A velocity variation reflection type oscillator comprising a cavity resonator having opposed wall portions provided with restricted apertures and defining a gap between said apertures, one of said wall portions including a hollow frusto-conical member converging toward said gap, means including said frusto-conical member and a cathode in alignment therewith for projecting a converging electron stream into said gap and substantially focused thereon, and an open-ended cylindrical repeller electrode opposite the other of said wall portions in alignment therewith and defining a converging electron optical mirror having its focus substantially at said gap.

9. A velocity variation reflection type oscillator comprising an enclosing vessel having a flexible wall portion, a cavity resonator fixedly mounted within said vessel and having opposed walls provided with aligned apertures, one of said walls being flexible and opposite said flexible wall portion, an electron gun opposite one of said walls and in alignment with said apertures, a repeller

electrode opposite the other of said walls and in alignment with the aperture therein, and rigid means connecting said flexible wall portion to said flexible wall.

10. A velocity variation reflection type oscillator comprising an enclosing vessel having a flexible wall position, a unitary assembly within said vessel including a foundation plate extending substantially parallel to said wall portion, said plate having an aperture therein, a cavity resonator within said aperture and having opposed walls provided with aligned apertures and one of which walls is flexible, an electron gun opposite one of said walls and in alignment with said aligned apertures, a hollow repeller electrode opposite the other of said walls and in alignment with said aligned apertures, clamping means securing said resonator, gun and repeller electrode to said foundation plate, and means rigidly coupling said flexible wall to said wall portion whereby said resonator may be tuned by flexure of said wall portion.

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