May 16, 1950 J. M. LAFFERTY 2,508,346

ULTRA HIGH FREQUENCY ELECTRON DISCHARGE DEVICE

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Fig. 1.

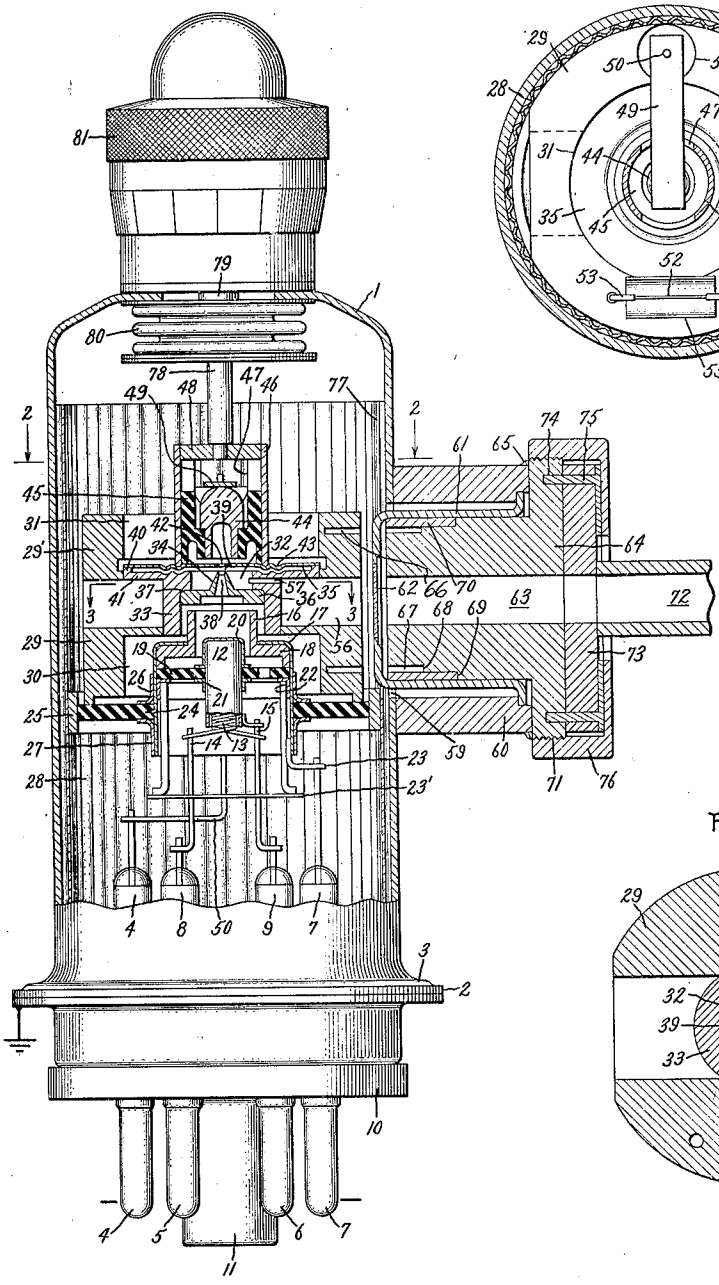
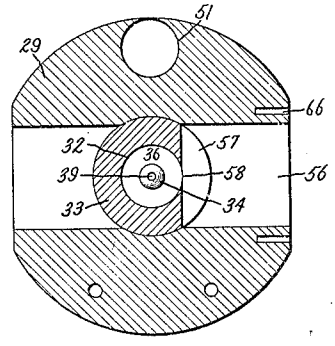


Fig. 2.

Fig. 3.



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Fig. 4.

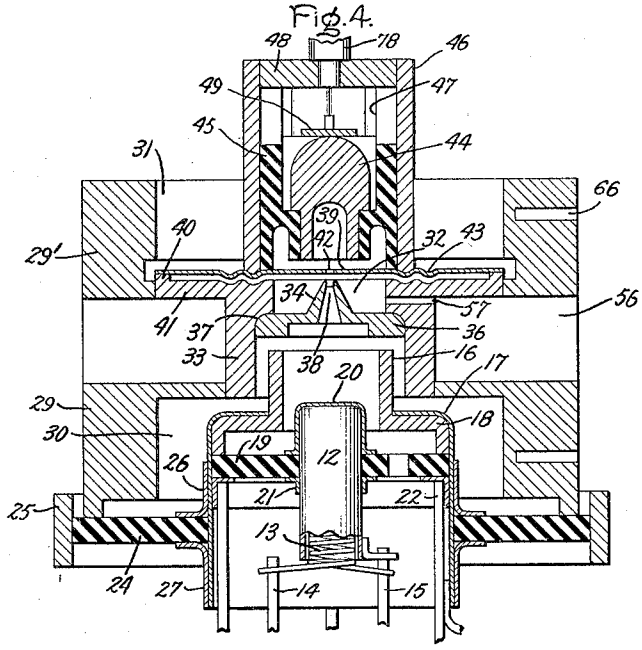
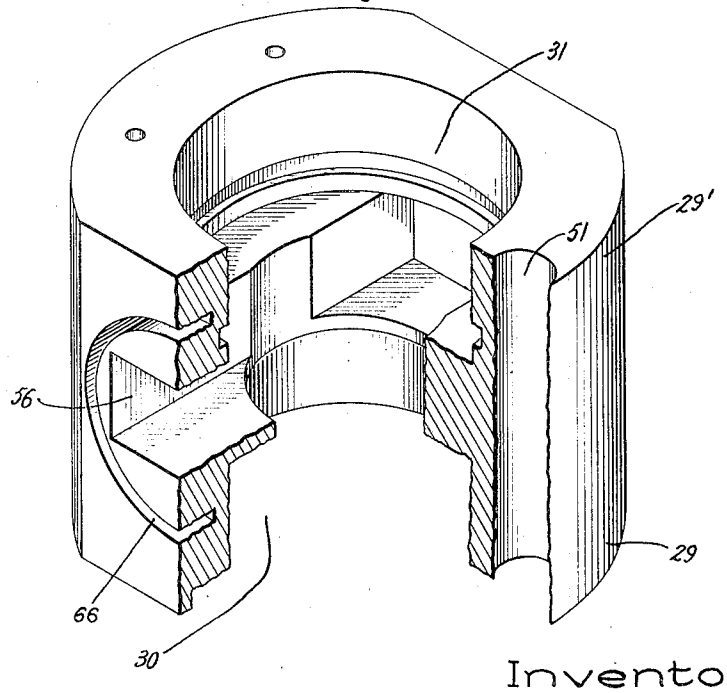


Fig. 5.



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UNITED STATES PATENT OFFICE

2,508,346

ULTRA HIGH FREQUENCY ELECTRON DISCHARGE DEVICE

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Application June 22, 1945, Serial No. 600,908

8 Claims. (Cl. 315—5)

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My invention relates to ultra high frequency electron discharge devices and more particularly to ultra high frequency electron discharge devices of the space resonant type employing velocity modulation principles.

In my copending application, Serial No. 506,501, filed October 16, 1943, entitled "Ultra high frequency electric discharge device," which is now patent 2,454,970, granted November 30, 1948, and assigned to the same assignee as the present invention, I disclosed an ultra high frequency oscillator of the reflex velocity modulation type in which a cavity resonator is provided. The operating frequency of the device is controlled either by mechanical means which adjusts the position of a tuning diaphragm, or electrically by controlling the potentials of a repelling electrode with respect to an anode structure. My present invention is directed to certain improvements in an ultra high frequency electron discharge device of this type.

It is an object of my invention to provide a new and improved ultra high frequency electron discharge device having a wave guide output system formed integral with the device.

It is another object of my invention to provide a new and improved cavity resonator in which a section of wave guide is formed integral with the resonator and coupled therewith.

It is still another object of my invention to provide a new and improved ultra high frequency electronic tube in which the internal tube structure is completely fabricated and then slipped into an envelope which contains an output wave guide.

It is a further object of my invention to provide a new and improved cavity resonator having a wave guide output in which impedance matching between the resonator and the wave guide is effected.

In accordance with one aspect of my invention, I provide a new and improved electron discharge device employing velocity modulation principles and including a metallic enclosing envelope having a window therein which is pervious to electromagnetic waves and which forms one end of an external wave guide section. The electron discharge device employs a cavity resonator to which is connected within the tube structure a section of wave guide supported adjacent the window in the envelope.

Another feature of my invention relates to the improved cavity resonator structure having a wave guide output formed integral therewith and in which means are provided for matching the

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high shunt impedance of the resonator to the relatively low impedance of the wave guide section.

For a better understanding of my invention, reference may be had to the following description taken in connection with the accompanying drawing and its scope will be pointed out in the appended claims. Fig. 1 is a longitudinal view, partly in cross section, of an electron discharge device of the velocity modulation type built in accordance with my invention. Figs. 2 and 3 are detailed cross-sectional views of this discharge device. Fig. 4 represents an enlargement of certain parts of Fig. 1, while Fig. 5 represents a perspective view of one part of Fig. 1.

Referring to Fig. 1, my invention is there illustrated as applied to an ultra high frequency electron discharge device comprising an enclosing envelope 1, preferably of rigid construction, comprising a metal having a low coefficient of thermal expansion such as Invar, and which defines at least in part an evacuated space in which are positioned various elements and electrodes described hereinafter. The envelope 1 is supported by and sealed to a base member 2 which comprises a flanged metallic part to which the lower part of the envelope 1 is secured by a suitable sealing means, such as by a solder 3. A plurality of seals and lead-in prongs or terminal posts 4—9, inclusive, are supported by an insulating part 10 of base member 2 in insulated relation and serve as externally accessible contacts for the electrodes in the electron discharge device. Of the aforementioned six lead-in seals and terminal posts, four are visible in Fig. 1 below the insulating part 10, while two, to wit, parts 8, 9, are seen in the sectional view of the interior structure of the electronic tube. An orientation protuberance for guiding the insertion of base member 2 and the terminal posts into an associated socket is provided and may comprise the externally located tubular extension 11 of insulating material formed integral with part 10.

Within the envelope 1 and preferably centrally located near the lower part of the defined space, I provide a thermionic cathode which may be of the indirectly heated type comprising a metallic cylinder 12, preferably coated on the exterior of the upper closed end with an electron emissive material, such as an alkaline earth metal, to serve as a source of electrons. A filament or heating element 13 is centrally positioned within the cylinder 12 and is supplied with energizing current through a pair of conductors

14, 15, conductor 14 being connected between one end of filament 13 and terminal post 8 and conductor 15 being connected to the terminal post 9. Conductor 15 is likewise connected to the outer surface of metallic cylinder 12 at its lower extremity.

To focus the electrons emitted at the upper end of the cathode cylinder 12, a focussing electrode is employed and may comprise a cylinder 16. The focussing cylinder 16 is supported within a metallic thimble member 17 which engages a shoulder portion 18 on the focussing cylinder 16. The cathode cylinder 12 likewise is supported within the thimble 17 by means of an insulating disk 19 which abuts the shoulder portion 18. The cylinder 12 is secured to the insulating disk 19 by a pair of flanged metallic washers 20, 21 which engage opposite sides of the disk 19 and are integrally attached to the cylinder 12, as by welding, the disk 19 being retained within the thimble 17 by means of a retaining ring 22. Focussing potentials are supplied to the electrode 16 by means of a conductor 23 which is connected to the lower end of the thimble 17 and to the terminal post 7. A shield 23', which may be formed of a suitable metal and which is supported from ring 22, is provided to prevent any electronic bombardment of the seals 4–9 and their associated conductors by cathode 12. Shield 23' also prevents any material which may be evaporated from the cathode from being deposited on the seals 4–9.

The thimble 17 containing focussing cylinder 16, in turn, is supported from a dielectric disk 24. The thimble 17 is attached to the disk 24 by means of a plurality of metallic rings 26, 27 which are welded to the outer surface of thimble 17 and have flanged portions engaging the disk 24. A metallic ring 25 is supported by and thermally connected to a heat conducting member 28 formed of a suitable metal having a low coefficient of thermal expansion, such as Invar, the ring 25 being secured thereto as by welding. The heat conducting member 28 may be corrugated, as shown, and have an outer diameter such that it slips within the envelope 1 making thermal contact therewith at each corrugation. At its lower end, the member 28 may rest upon the upper end of base 2 and be attached thereto in any suitable manner, not shown, such as by welding.

An anode structure defining a cavity resonator is provided comprising a substantially cylindrical metallic block 29 which rests upon the ring 25 and may be mechanically secured thereto, as by soldering. The lower portion of the block 29 is provided with a centrally positioned recess 30 into which the thimble 17 extends. An upper portion 29' of the anode structure is provided with a similar centrally positioned recess 31 on its upper surface and the cavity resonator of the device is positioned within this recess. After the resonator is so positioned, the two portions of the anode structure are soldered together to form an integral structure.

The cavity resonator 32 comprises a tubular metallic cylinder member 33 which passes through a centrally located aperture in the block 29, a conical member 34, and a flexible diaphragm 35. The conical part 34 is circular in form and has a flanged portion 36 which engages a shoulder 37 on the inner surface of the tubular member 33. The conical part 34 likewise has a tapered aperture 38 through which the electron beam passes and which defines, with one boundary of the cavity resonator 32, a velocity modulating gap 39 for the electrons constituting the beam. The flexible metallic diaphragm 35, which provides means to control the natural frequency by controlling the physical dimensions of the cavity resonator 32, is seated upon a circular flange 40 extending upwardly from the top surfaces of a flange 41 which forms the upper end of the cylinder 33. The diaphragm 35 is provided with a central aperture 42 to afford a communicating path between the cavity resonator and the electrode reversing region described hereinafter. The radial distance from the wall of resonator 32 to the inner surface of the circular flange 40 is made approximately equal to a half wave length at the desired operating frequency of the electron discharge device so that the diaphragm 35 and the top surface of flange 41 between the cavity resonator 32 and flange 40 define an annular portion and form a section of radial transmission line of a length such that the short-circuit at one end, constituted by the flange 40, is reproduced to appear as a very low impedance at the inner end of the section of radial transmission line. The diaphragm 35 and the upper surface of the cylinder 33 are provided with a plurality of corresponding concentric grooves 43, the function of which is pointed out in detail hereinafter.

Control means are provided for establishing electron repelling electric fields and may take the form of a cylindrical metallic member 44 which is supported by a dielectric cylinder 45 which rests upon the upper surface of the diaphragm 35. The dielectric cylinder 45, in turn, is secured within a retaining housing formed by a hollow vertical metallic cylinder 46 having a lateral opening 47. The cylinder 46 rests at its lower end in one of the grooves 43 on the upper surface of the diaphragm 35. At its upper end, the cylinder 46 contains a transverse member 48. So constructed the members 46, 48 form a yoke which surrounds the electrode 44 and which rests upon the upper surface of the diaphragm 35, preferably being soldered in one of the grooves 43.

Energizing potentials are supplied to the repelling electrode 44 by means of a transverse conductive strip 49, best seen in Fig. 2, which extends through lateral opening 47 and one end of which is connected to the upper end of the electrode 44. The other end of strip 49 is connected to a vertical conductor 50 which passes through a longitudinal opening 51 in the block 29 to connect with the terminal post 4. Also shown in Fig. 2, is the gettering means 52 in the form of a fusible conductor, the ends of which are connected by means of conductors 53, 54 to terminal posts 5, 6. Near their points of connection to the gettering means 52, the conductors 53, 54 are curved and serve to support a trough 55 positioned between the gettering means 52 and the electrodes of the discharge device.

In order to derive ultra high frequency energy from cavity resonator 32, a section of a rectangular wave guide 56 is formed integral with the anode block 29 by milling a transverse rectangular slot in the block 29. The tubular cylinder 33, as seen in Fig. 3, constitutes an end wall of the section 56 of the wave guide. Electromagnetic waves are coupled between the cavity resonator 32 and wave guide 56 by means of a small slot 57, which is cut in the metallic cylinder 33 just below the flange 41. The width of the slot 57, as best seen in Fig. 3, is such that a very small opening 58 is formed in the side wall of the cavity resonator 32. In this construction, the cylinder 33 forms a step at the end of the wave guide and the height of the slot 57 is so corre-

lated with the dimensions of this step that the high shunt impedance of the cavity resonator 32 is matched with the relatively low impedance of the wave guide 56.

In order to effect the transfer of energy from the wave guide 56 to a utilization circuit external to the electronic tube, the envelope 1 is provided with a lateral opening 59 surrounded by an external tubular collar 60. Within the collar 60 is disposed a metallic thimble 61 which extends slightly through the opening 59 into the region within envelope 1. At its end which projects through the opening 59, the thimble 61 is provided with an aperture across which is sealed a vitreous window 62, the window 62 being placed directly in front of the wave guide section 56. Preferably, the window 62 is formed of a suitable glass which is pervious to electromagnetic waves, transmitting them dielectrically with a minimum amount of reflection. In the construction of this window, the dielectric constant of the glass, its thickness and its surface dimensions determine its reflective properties. These parameters are so correlated that the window provides minimum reflection and optimum transmission at the desired operating frequency. Adjacent the outer surface of the window 62 is an output section of rectangular wave guide 63, the dimensions of which correspond to the dimensions of the wave guide section 56. The section 63 is formed in a metallic block 64 which is supported from the collar 60 by any suitable means, such as the welds 65.

In order to obtain optimum transmission between the wave guides 56 and 63 through the window 62, a pair of half-wave chokes 66, 67 are provided. The choke 66 may be formed by a circular groove cut in the anode block 29, the bottom of the groove being displaced from the wave guide section 56, in a manner well known to those skilled in the art, by a distance substantially equal to a half wave length at the desired operating frequency of the electron discharge device. The choke 67, which is also in the form of a circular groove, is constructed by cutting shoulders 68, 69 on the block 64 and supporting a metallic sleeve 70 on the shoulder 69. In the construction of this choke, shoulder 68 likewise is displaced from the edge of the wave guide section 63 by a distance equal to a half wave length at the desired operating frequency of the electronic tube.

In order to permit coupling of an external wave guide to the wave guide section 63, the block 64 is provided with threads 71. A wave guide 72 which is to be connected with the wave guide 63 is provided at its coupling end with a circular flange 73 through which pass positioning pins 74. The pins 74 are arranged to fit in holes 75 provided in the block 64. The oriented wave guide 72 is attached to the wave guide 63 by means of a nut 76 which engages the threads 71.

An important feature of my invention, which includes a wave guide output formed integral with a cavity resonator and coupled with an external wave guide, is that the internal tube structure may be completely fabricated and then slipped into the envelope 1, which is previously formed with the transparent wave guide window and output wave guide in position. To effect such a method of assembling the tube, the corrugated heat conducting member 28 is provided with a longitudinal slot 77 of such dimensions that it passes around the thimble 61 and assists in orienting the internal tube structure in final assembly of the device.

As a means for mechanically controlling the position of the diaphragm 35, an externally accessible actuating means is provided for exerting different amounts of pressure thereon, thereby controlling the dimensions of the cavity resonator 32. This means may comprise an assembly supported by the flat top of the envelope 1 and may include an actuating rod 78 constituting a vertically adjustable or positionable member of the actuating means. The rod 78 is connected to the transverse member 48. As previously described, the transverse member 48 is connected to the cylinder 46 which is soldered at its lower ends to the diaphragm 35. Alternatively, the cylinder 46 may be seated in one of the annular grooves 43 and the diaphragm may be formed to have a resiliency tending to restore itself to a vertical position whereupon the diaphragm is maintained in contact with the cylinder 46. In such instances, the control of the form and position of the diaphragm is accomplished by the amount of vertical pressure exerted thereagainst.

Surrounding the vertical rod 78 is a hollow tuning screw 79 which is welded or brazed around the top of rod 78 to form a vacuum-tight seal, not shown. At its lower end, the hollow tuning screw 79 is welded or soldered to a metallic bellows 80 sealed to the inner surface of envelope 1 to provide a sealing structure of deformable character in the upper portion of the envelope.

Above the envelope 1 and in an externally accessible position, a micrometer adjusting means 81 is provided to actuate the rod 78 whereby, upon actuation, the rod 78 is moved to position the diaphragm 35 in minutely determinable degrees to obtain a desired control in the operating frequency of the device. Preferably, the rod 78, the transverse member 48, the supports 46, 47, tuning screw 79, and micrometer 81 are composed, similar to envelope 1 and member 28, of a metal having a low coefficient of thermal expansion, Invar being well suited for this construction. So constructed, the device experiences little change in operating frequency as the operating temperature varies.

Fig. 2 is a cross-sectional view of the device shown in Fig. 1 along the lines 2—2 and represents the disposition of the reflector electrode 44, the flat conductor 49, and the getter 52, all with respect to the anode block 29. Fig. 3 is a cross-sectional view of the anode block 29 of Fig. 1 taken along the lines 3—3 and shows the general circular form of the block 29 and the location of the transverse slot which forms the wave guide 56. This figure also shows the position of the cavity resonator 32 and the coupling aperture 58 with respect to the wave guide 56.

In considering the operation of the embodiment of my invention described above, it may be stated generally that the electron discharge device is of the velocity modulation type wherein the electron beam is velocity modulated periodically so that successive groups of electrons are alternately accelerated and decelerated tending to group the electrons in the beam after the beam has traversed the velocity modulation gap 39 in the resonator 32. The particular form of electron discharge device described above operates in accordance with reflex principles. After undergoing velocity modulations, the electrons are given an opportunity to assume a charge density distribution incident to the effect of the velocity modulation and are reversed in the direc-

tion of travel to re-enter the cavity resonator delivering energy to the electromagnetic fields thereof and through the output aperture 58 to the wave guide section 56. In the device described above, an electron beam is established by virtue of the unidirectional potential impressed between the anode construction comprising the block 29 which is maintained at the potential of the envelope 1 and the cathode cylinder 12. The electrons of the beam initially assume a velocity determined by the differences in potential impressed between the anode and cathode. Negative potential is supplied likewise to the focussing cylinder 16 which tends to restrict the size of an electron beam, confining it to a relatively small area in order that a large percentage of the electrons pass through the cavity resonator 32 through the conical part 38. Assuming an excitation of the cavity resonator 32 by virtue of sporadic motion of electrons across the gap 39 during starting operation, the resonator is set into an oscillation and there is established across the modulating gap 39 between the upper edge of the conical part 38 and the diaphragm 35 an alternating high frequency potential incident to the electromagnetic field within the cavity resonator. By virtue of the alternating nature of this potential, electrons which are in the effective region of the gap 39 during periods of time when the diaphragm 35 is positive with respect to the conical part 38 are undergoing an acceleration. Consequently, the electrons, after traversing the gap 39, pass through the aperture 42 and proceed into the region of the field produced by the reflecting electrode 44 which, preferably, is maintained at a negative potential with respect to the cathode. The distance which the electrons proceed in their paths beyond the diaphragm 35 is a function of the kinetic energy of each electron. It is well understood that the energy of an electron may be referred to a voltage which will accelerate the electron to a particular velocity, establishing that amount of kinetic energy. The faster electrons obviously travel further toward the reflecting electrode before they are stopped and reversed than do the slower electrons.

The operating frequency of the system may be controlled either by controlling the physical dimensions of the cavity resonator 32 by means of the micrometer adjusting means 81, or by controlling the voltage impressed upon the various electrodes including the voltage of the cathode cylinder 12 with respect to the anode and the voltage of the reflecting electrode 44. Considering first the control of the operating frequency by virtue of change in the natural resonance frequency of the cavity resonator, the position of the diaphragm 35 controls one boundary of the resonator and, consequently, controls its natural frequency. Ready adjustment of the position of this boundary is obtained by movement of the rod 78.

The operating frequency, as stated above, may also be controlled by variation of the voltages impressed upon the reflecting or repelling electrode 44, in this manner controlling the transit time of the electrons in the beam and consequently controlling the phase of charge density modulated electrons which are returned to the cavity resonator with respect to the field thereof. By using this method of controlling the operating frequency, it has been found that a final adjustment of the range of frequency may be obtained.

One of the features of my invention is the particular configuration of the reflecting electrode 44. As may be seen by reference to Fig. 1, this electrode is in the form of a hollow cylinder having its open end adjacent the aperture 42 in the diaphragm 35. The configuration of the electrode, moreover, is such that it provides both optimum transit time and optimum focussing of electrons so that they return through aperture 42 and in proper phase relation with the electromagnetic fields of the resonator.

It has been found in the operation of frequency devices of the type disclosed that excellent transmission of energy is obtained from the cavity resonator 32 to an external wave guide by virtue of the construction in which all coupling between the resonator and a wave guide is effected within the tube itself, and that transmission of energy between the wave guide sections 56, 63 is effected with substantially little reflection of electromagnetic waves. This result is attributable in large part to the construction of the wave guides and the window in which chokes are provided and formed integral with the anode block and output guide 63.

While I have shown particular embodiments of my invention, it will of course be understood that I do not wish to be limited thereto, since various modifications may be made, and I contemplate by the appended claims to cover any such modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States, is:

1. An electrode structure for an ultra high frequency electron discharge device of the cavity resonator type comprising a metallic block having a central aperture therein, a hollow metallic member supported in said aperture defining a portion of a cavity resonator, said member comprising an entrance part for receiving electrons and producing a narrowly defined control region within said resonator, a deformable diaphragm positioned opposite said entrance part and having an aperture therein, said block having a transverse slot defining a wave guide, said metallic member extending across said slot and forming an end wall for said wave guide, said metallic member having a transverse slot whereby energy from said resonator is coupled into said wave guide.

2. An ultra high frequency electron discharge device comprising an enclosing metallic envelope, a cavity resonator positioned within said envelope, means within said envelope for exciting said resonator, a section of wave guide of the hollow pipe type supported within said envelope, means coupling said resonator and said section, said envelope having a dielectric window formed continuously therewith and positioned opposite one end of said wave guide, means supported by said envelope defining a second section of wave guide external to said device, said sections of wave guide being aligned with each other and said window being disposed between said sections, whereby electromagnetic waves from said resonator are transmitted between said sections of wave guide through said window, and choke means surrounding said sections adjacent said window to facilitate transmission of electromagnetic waves through said sections.

3. A device as in claim 2 wherein said choke means comprises annular grooves within each of said sections.

4. An electron discharge device of the velocity

modulation type comprising an envelope, a plurality of co-operating electrodes within said envelope including a resonant electrode structure comprising a metallic block having a central opening therein, metallic means supported within said opening having walls defining a generally annular cavity of diameter substantially less than the transverse dimension of said opening, and a circular flexible diaphragm of diameter greater than said cavity spaced from said metallic means and defining therewith a cavity resonator including said cavity and an annular portion between said metallic means and said diaphragm, said metallic means and said diaphragm having aligned apertures through which an electron beam may be projected to excite said resonator.

5. A device as in claim 4 wherein the radial dimension of said annular portion between said means and said diaphragm is substantially equal to one-half of the wave length at a predetermined operating frequency of said device.

6. An electron discharge device of the velocity modulation type comprising an envelope, a plurality of co-operating electrodes within said envelope including a resonant electrode structure comprising a metallic block having a central opening therein, metallic means supported within said opening having walls defining a generally annular cavity of diameter substantially less than the transverse dimension of said opening, and a circular flexible diaphragm of diameter greater than said cavity spaced from said metallic means and defining therewith a cavity resonator including said cavity and an annular portion between said metallic means and said diaphragm, said metallic means and said diaphragm having alinged apertures through which an electron beam may be projected to excite said resonator, said block having a second opening defining a metallic wave guide, said metallic means forming an end wall for said wave guide and including means intercoupling said cavity resonator and said wave guide whereby energy from said resonator may be coupled into said wave guide, said envelope including a window pervious to electromagnetic waves at one end of said wave guide.

7. A device as in claim 6 including means defining a wave guide external to said envelope coupled to said first mentioned wave guide through said window.

8. An electron discharge device of the velocity modulation type comprising an envelope, a plurality of co-operating electrodes within said envelope including a resonant electrode structure comprising a metallic block having a central opening therein, metallic means supported within said opening having walls defining a generally annular cavity of diameter substantially less than the transverse dimension of said opening, a circular flexible diaphragm of diameter greater than said cavity spaced from said metallic means and defining therewith a cavity resonator including said cavity and an annular portion between said metallic means and said diaphragm, said metallic means and said diaphragm having aligned apertures through which an electron beam may be projected to excite said resonator, said block having a second opening defining a metallic wave guide, said metallic means forming an end wall for said wave guide and including means inter-coupling said cavity resonator and said wave guide whereby energy from said resonator may be coupled into said wave guide, said envelope including a window pervious to electromagnetic waves at one end of said wave guide, and means defining a wave guide external to said envelope coupled to said first mentioned wave guide through said window, said block and said last-mentioned means each including grooves defining chokes surrounding said wave guides and positioned adjacent said window.

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