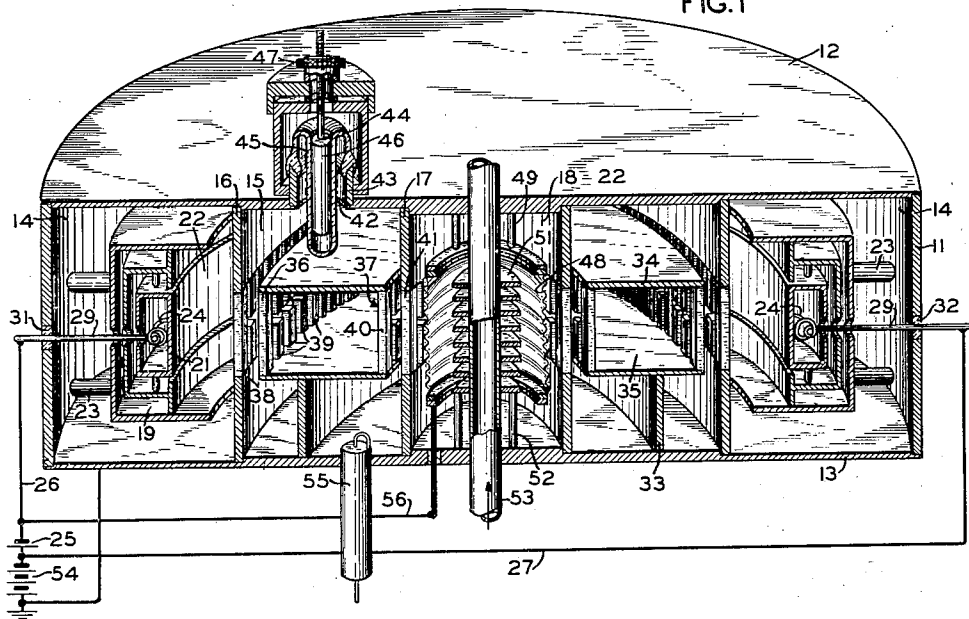
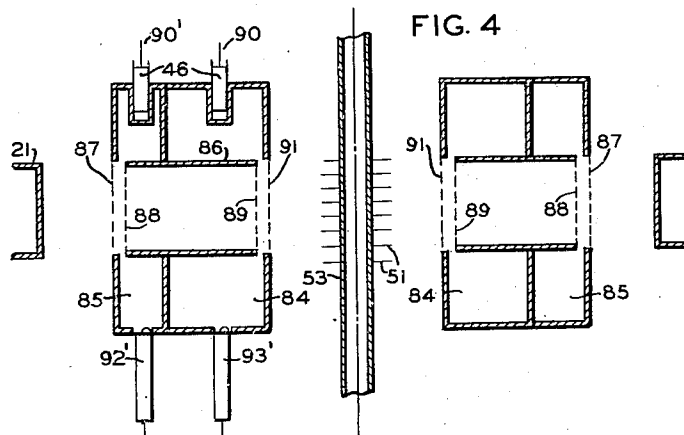


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HIGH-FREQUENCY APPARATUS

3 Sheets-Sheet 1

FIG. 1



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Filed Dec. 7, 1942

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FIG. 2

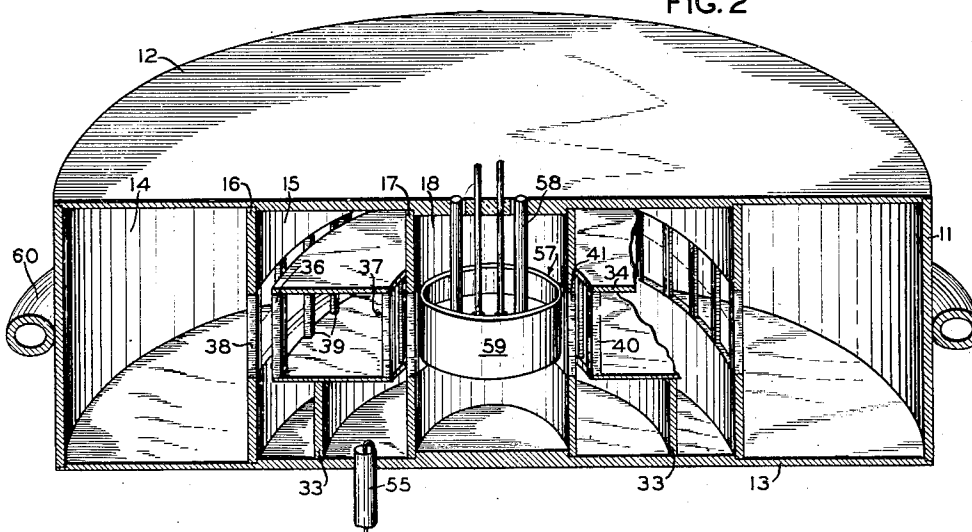
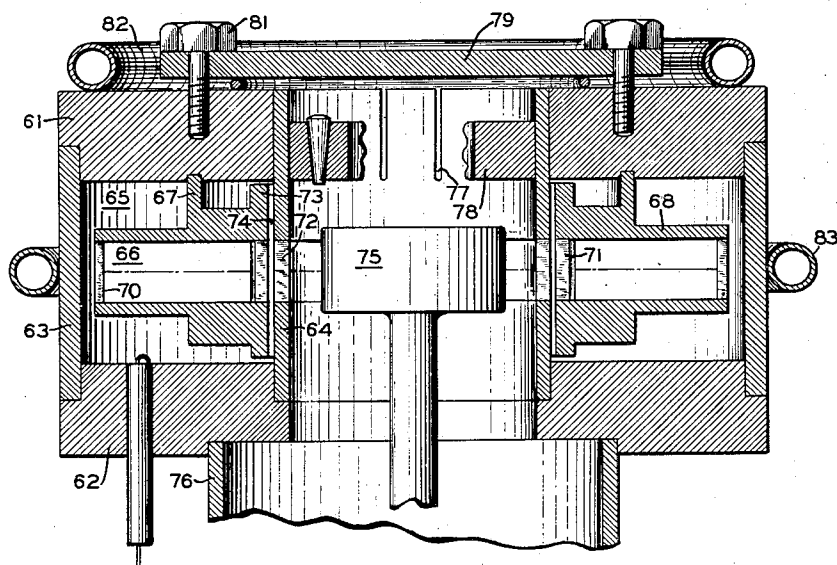


FIG. 3



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Filed Dec. 7, 1942

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FIG. 5

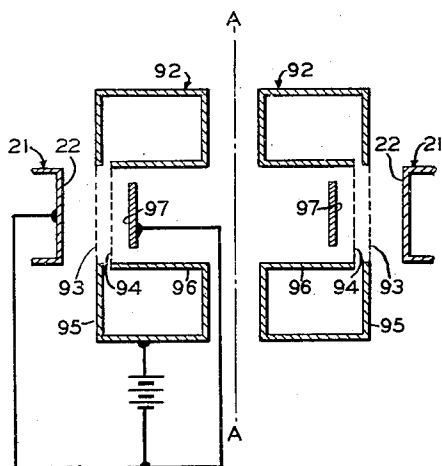


FIG. 7

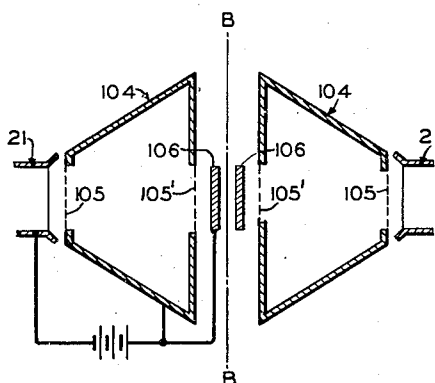


FIG. 6

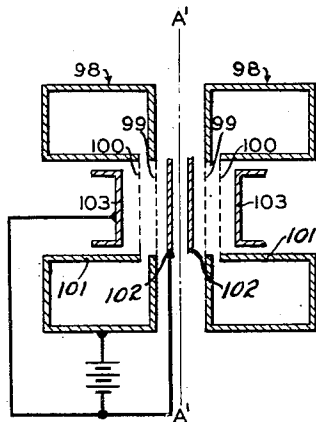
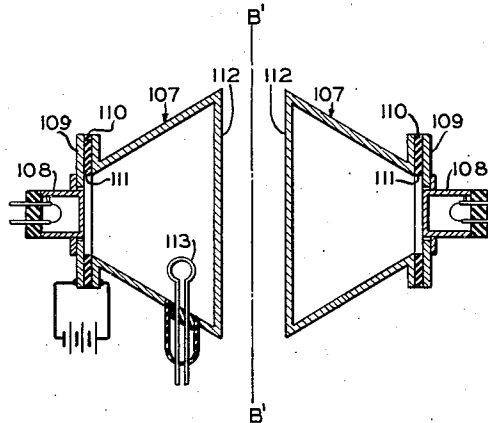


FIG. 8



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2,466,067

HIGH-FREQUENCY APPARATUS

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Application December 7, 1942, Serial No. 468,307

6 Claims. (Cl. 315—6)

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This invention relates to ultra high frequency apparatus and more particularly to space resonator devices having special arrangements for direction and velocity modulation of an electron stream.

The invention will be described in its embodiment with electronic devices of the type wherein an electron beam is velocity modulated due to passage through a high frequency electric field produced by a hollow resonator.

In order to handle large power inputs and outputs in such devices it has heretofore been proposed to increase the cathode or current emission area by designing the resonators and associated grid structure in the form of figures of revolution about various axes, so that the cathode and grid areas are made relatively large without changing the resonating characteristics. Some of these structures are shown in United States Letters Patent No. 2,259,690 in which we are co-inventors.

The present invention is an improvement over the development represented by said patent and is especially directed to velocity modulated electron beam devices for high power operation wherein the resonator, grid and cathode structures preferably comprise figures of revolution in special highly efficient association with a new arrangement for passing the electron beam through the resonator field.

It is therefore a major object of our invention to provide an ultra high frequency device of the velocity modulated electron beam type having novel internal construction and unusually efficient operational characteristics.

A further object of the invention is to provide a novel high frequency device of the velocity modulation type wherein a hollow resonator means is arranged about an axis and an electron beam is projected transversely of that axis through the field produced by the resonator.

A further object of the invention is to provide a novel ultra high frequency hollow resonator device of the velocity modulation type arranged about an axis wherein an electron beam is transversely, preferably radially, projected through the device. The arrangement of the figure about the axis is preferably, but not essentially, that of revolution.

It is a further object of the invention to provide an ultra high frequency device of the velocity modulated electron beam type having a hollow resonator substantially in the form of a figure of revolution about an axis and an electron

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beam transversely projected through the figure. Pursuant to this object the electron emitter may be shaped and located so as to surround or be surrounded by the resonator as desired, and the electron stream is generally radially directed.

A further object of the invention is to provide an ultra high frequency device of the velocity modulation type having a resonator as a single tuned oscillation circuit and wherein therein novel arrangements are provided for ample cooling of the device.

A further object of the invention is to provide a novel ultra high frequency device of the velocity modulated electron beam type wherein the relative capacities of the input and output electrode gaps are designed for improving the resonator characteristics.

A further object of the invention is to provide a high frequency velocity modulation device embodying a hollow resonator in the form of a figure of revolution about an axis and having novel associated grid and reflector arrangements.

Further objects of the invention will presently appear as the description proceeds in connection with the appended claims and the annexed drawings in which:

Fig. 1 is a perspective view partly in section through the axis of a preferred form of high frequency device embodying the principles of the invention. The cathode here surrounds the resonator.

Fig. 2 is a perspective view partly in section of another embodiment of the invention wherein the cathode is centrally disposed within the resonator.

Fig. 3 is a sectional view along the axis of a still further embodiment of the invention, similar to Fig. 2, but including a novel capacity loading arrangement within the resonator.

Fig. 4 is a diagrammatic representation of a variation of the principles of structure of Fig. 1, wherein the resonator fields for the input and output grids are individual so that the device may be selectively employed as either an oscillator or amplifier.

Fig. 5 is a diagrammatic representation of the invention as embodied in a reflex device having an internal reflector.

Fig. 6 is a further diagrammatic representation of a reflex device according to the invention similar to Fig. 5 but employing a resonator of different shape.

Fig. 7 is a diagrammatic representation of a further embodiment of the invention as applied to another form of resonator.

Fig. 8 is a diagrammatic representation of a still further embodiment of the invention similar to Fig. 7 but using a different manner of extracting output energy.

As will appear in the following detailed description, the device of the invention is primarily designed by developing, preferably by rotation about a selected axis, a generally toroidal structure having the same shape and appearance in cross-section as a simple velocity modulation device and having its grid sections substantially longitudinally disposed in the path of generally transversely or radially directed electrons from an external or internal cathode surface. The development of the figure about the axis is not limited to continuous revolution, such as a circle or ellipse, for example, but may include discontinuous revolution, such as a rectangle, as may be desired. In effect, the invention is chiefly concerned with what may be designated as a radial electron beam velocity modulation device, as distinguished from the usual velocity modulation devices embodying electron beams directed axially of the hollow resonator.

Referring to Fig. 1 the device of the invention comprises a hollow metal cylinder having a side wall 11 and opposite end walls 12 and 13. The interior of the cylinder is divided into annular compartments or chambers 14 and 15 by annular walls 16 and 17, respectively, which extend the full length of the cylinder. Wall 17 encloses a central cylindrical compartment 18. Walls 11, 12, 13, 16 and 17 are all of copper or some good electrically conducting material or may be plated with a good conducting material.

A cathode assembly comprising a suitable annular support frame 19 carrying an annular hollow cathode element 21 which presents a uniform electron emitting surface 22 parallel to wall 16 is disposed in compartment 14. Frame 19 is rigidly mounted on a series of insulator posts 23 extending from wall 11, and is of suitable shape and size to extend over for focusing cathode emission toward the electrodes. The electron stream from surface 22 is projected directly toward wall 16.

The cathode is energized by a coiled wire filament 24 which is heated to incandescence by energy from battery 25 through lead 26 and return lead 27. Leads 26 and 27 include terminals 28 and 29 extending through glass or like insulated gas tight bushings 31 and 32 in wall 11.

Walls 16 and 17 and the associated portions of walls 12 and 13 intersected thereby define the outer walls of the cavity resonator of the device. Within compartment 15, an upstanding relatively thick metal wall 33 supports a hollow cylindrical metal tubular structure comprising parallel top and bottom walls 34 and 35 and parallel cylindrical walls 36 and 37. Wall 33 provides a good heat conductive path of sufficient capacity to efficiently conduct the heat from the internal walls 34, 35, 36 and 37 to the exterior where it may be dissipated as by cooling. This is an appreciable advantage over the structures of Patent No. 2,259,690.

As shown in Fig. 1, walls 16, 36, 37 and 17 are provided or formed with annular grid sections 38, 39, 40 and 41, respectively, aligned radially with each other and cathode surface 22. While these grid sections are illustrated as circumferentially spaced metal strips or bars having equal sized openings therebetween, it is obvious that any suitable form of grid segments may be employed. Further, any convenient number of the strips or

bars may be discontinuous as shown in the drawings, and only as many full length strips or bars as are necessary for proper support and good heat conduction from the grid and wall 22 need be provided. This provides a generally centrally apertured grid reducing interception of the electron stream at its central point.

If desired, the grid strips or bars may be removable elements suitably mounted in slots formed in the respective walls supporting them as shown.

Grid sections 38 and 39 have their openings aligned and serve as the beam-controlling or input grids of the resonator, while grids 40 and 41 also have their openings aligned and serve as the beam-excited or output grids of the resonator. Input electrodes 38 and 39 are spaced apart materially less than are output electrodes 40 and 41, for reasons disclosed in said Patent No. 2,259,690, for most efficient operation of this type of device. The space between grid sections 39 and 40 serves as the drift space of the resonator wherein the electrons become velocity grouped.

End wall 12 is apertured at 42 for introducing a tuning element into resonator compartment 15. A metal collar 43 upstands from aperture 42 and is closed by a glass cover 44 having a reentrant tubular portion 45 projecting within compartment 15. A metal plunger 46 is slidably mounted in tubular guide 45, and the displacement of plunger 46 is measurably controlled by the calibrated control knob 47. Knob 47 is mounted on the threaded end of the plunger shaft which in turn is slidably but non-rotatably mounted in a suitable bracket as shown. Rotation of knob 47 produces translation only of plunger 46. The purpose of preventing rotation is to eliminate possible lateral deviation of plunger 46 due to guide path inaccuracies.

An annular suppressor grid 48 is centrally mounted, as by insulator posts 49, within compartment 18. Within grid 48, a stack of axially spaced annular fins or flanges 51 are supported, as by posts 52. A metal pipe 53 which primarily serves as a collector electrode for receiving electrons passing through grid 48 and fins 51 extends axially of the device through the end walls 12 and 13 and in contact with these walls and flanges 51 and has suitable connections (not shown) for continuously circulating cooling fluid such as water therethrough.

In operation the uniform annular stream of electrons emitted by surface 22 passes first through input grids 38, 39 which initiate the velocity modulation by causing alternate acceleration and retarding of the electrons, and then the stream passes into the drift space between grids 39 and 40 which is proportioned to permit the bunching operation. The bunched electron stream then passes through output grids 40, 41 at which energy is derived from the velocity modulated beam and delivered to maintain the common electromagnetic field within compartment 15 at resonant frequency. Battery 54 connected to battery 25 and to wall 13 provides the direct current driving voltage for the electron stream, and a suitable concentric line and antenna loop device 55 is provided for further extracting ultra high frequency energy from the resonator field. In general, the energy conversion and the phenomenon of velocity modulation, are the same as in the usual velocity modulation device, so that further description of the same is unnecessary.

The general advantages of this type of device wherein the resonator field is common for the

input and output grids are described in said Patent No. 2,259,690 to which reference is made for further detail. For simple devices of this type using a single tuned circuit, it has been found very difficult to remove heat from the interior of the device due to lack of heat conducting paths. In the invention, provision of a structure of revolution affords large grid areas for widely distributing the internal heat, and wall 33 is sufficiently thick to provide good heat conduction to the exterior where any suitable cooling such as an air blast may be employed.

Variation of the resonant frequency of resonator chamber 15 is accomplished by adjustment of knob 47 to change the displacement of plunger 46 within the chamber. The glass tubing 45 of course does not appreciably disturb the field within the resonator, but displacement of the metal plunger is effective upon the electromagnetic field.

Many of the electrons passing through final grid 41 are intercepted by the relatively fine woven suppressor grid 48 which is connected by an insulated return lead 56 to the cathode or to a point between cathode and input electrode potential, thus returning electrons to the supply and improving the overall efficiency of the device. Electrons passing through grid 48 and fins 51 are collected by pipe 53 where they give up their energy as heat to be radiated by the fins or conducted away by the coolant within the pipe. Grid 48 and fins 51 are of such nature as to intercept and thereby suppress the harmful effects of secondary emission of electrons from pipe 53. Grid 48 is cooled by radiation to compartment 18, which in turn is cooled by fins 51, pipe 53 and radiation from the end walls.

The entire interior of the device bounded by gas tight walls 11, 12 and 13 is evacuated, and all lead-in or pipe connections are of such nature as to preserve the vacuum.

The above-described device is an efficient high power velocity modulation device having very large associated cathode and grid areas. In its preferred form as set forth, the resonator describes a continuous developed figure, preferably of revolution, which may be rectangular in cross-section, circular, or of any equivalent shape, about the central axis as noted in the objects of our invention. The invention is thus of sufficient scope to embrace the use of any generally toroidal structure of regular revolution or equivalent or similar disposition about an axis. The large exposed cathode surface 22 provides for maximum current output without increasing the current density of the surface, thereby enabling it to operate at relatively low and safe filament temperatures for high power output. Another advantage is that this is the only single tuned circuit resonator known to us which has an efficient cooling system for extracting heat from the interior.

The embodiment of the invention illustrated in Fig. 2 is the same as Fig. 1 except that the cathode is disposed inside the figure of revolution defined by the resonator so that the electron stream is projected radially outwardly therefrom. For convenience in illustration, certain of the grid bars are not shown but are merely indicated by the dot-dash lines. Preferably the electrodes are as in Fig. 1. Corresponding parts of the device are designated by the same numbers as in Fig. 1.

In Fig. 2, compartment 18 is the cathode compartment. The cathode assembly 57 is supported

from wall 12 by a pair of insulator posts 58, and the electrical leads supplying energy for heating the filament and introducing the accelerating voltage for the cathode are sealed in a gas tight insulating bushing in wall 12. As shown, cathode 57 is preferably of simple cylindrical form, although any desired shape presenting an outwardly emitting surface may be employed. The electron emission surface 59 of the cathode is annular, parallel to grid 41 and of considerable area. It projects a uniform annular stream of electrons through the resonator as above explained, with the exception that in Fig. 2 grids 40 and 41 are the input grids while grids 38 and 39 are the output grids. Electrons which emerge from grid 38 strike annular collector wall 14, there giving up energy as heat to be radiated or conducted away by cooling coil 60.

The internal cathode of Fig. 2 is peculiarly efficient in that it enables very accurate direction and focusing of the electron stream. It further does not present all the special internal cooling problems inherent in Fig. 1, where all the electrons are directed toward a common point, and its cathode area is sufficiently large to efficiently handle relatively high power. The device of Fig. 1 is more desirable however for very high power tubes.

Fig. 3 illustrates a radial device similar to Fig. 2 but having special arrangements for capacity loading the input grid circuit. Annular top and bottom plates 61 and 62 are rigidly secured as by welding to a hollow cylindrical external body wall 63 which holds them in spaced relation. Bottom plate 62 is internally shouldered for seating an annular inner wall 64 which fits snugly within the inner periphery of upper plate 61 as shown. Plates 61 and 62 and walls 63 and 64 define the outer walls of resonator chamber 65 of this device.

Within chamber 65 is disposed an annular grid supporting a drift space member 66 having an upstanding integral rim 67 mating with a cooperating groove in the bottom of plate 61, and rim 67 is secured as by welding to plate 61 for mounting member 66 in the resonator.

Member 66 comprises upper and lower annular plates 68 and 69 held together in spaced relation by inner and outer series of grid bars 70 and 71, respectively. Preferably plates 68 and 69 are formed with spaced slots about their entire inner and outer circumferences for receiving the grid bars, which in turn are welded or similarly permanently secured thereto. As in Fig. 1, certain of the bars may be discontinuous at the grid centers to prevent interference with the passage of the central portion of the electron stream.

Inner wall 64 is formed with a grid section 72 having openings in alignment with grid 71. The space between grids 71 and 72 is considerably smaller than the space between grid 70 and wall 63. The voltage across the output gap between electrode 70 and wall 63 is higher than across the gap between electrodes 71 and 72, the field intensity also being greater between the output electrodes.

The area of inner peripheral surface 73 of member 66 is parallel and coextensive with wall 64 and is purposely made very large as shown so as to increase the capacity space 74 in the input electrode circuit. This feature together with the relation between spacings of the input and output electrodes assures that a voltage node will exist in the field within the resonator approximately opposite support 67. This facili-

tates tuning of the resonator in the manner shown in Fig. 1, which tuning effectively displaces such a node, by making the tuning adjustment less sensitive.

Cathode 75, of similar shape to that at Fig. 2, is supported centrally of the device by suitable means (not shown) in base 76. The electron stream from cathode 75 is velocity modulated during passage through the resonator, and the usual concentric transmission line and loop 55 is arranged to extract ultra high frequency energy from the field.

The upper end of wall 64 is formed with a series of longitudinal slots 77 so as to be expansible, and a suitable annular expansion ring 78 is inserted therein to retain wall 64 fixed in its seat. A cover 79 closes the top of the device, being secured thereto as by bolts 81 which when tightened compress a flexible sealing ring between the cover and the plate 61. Cooling fluid coils 82 and 83 conduct heat away from the device during operation, wall 63 serving as the collector electrode. The interior of the device is exhausted and the vacuum maintained during operation.

Fig. 4 diagrammatically illustrates a high power radial device having an external annular cathode 21 similar to that in Fig. 1. As in Fig. 1, the resonator is in the form of a figure of revolution about the central axis but the input and output resonator circuits are maintained electrically separated so that the device may be used as an amplifier. This may be accomplished in Fig. 1 simply by providing a support wall similar to wall 33 but extending between walls 12 and 34, thus dividing the space between walls 16 and 17 into two physically separate resonator chambers instead of the common chamber 15 of Fig. 1.

Referring to Fig. 4, inner and outer annular resonators 84 and 85 are concentric about their common axis. An annular drift space enclosure 86, which may be formed as in Figs. 1 and 3, extends between and projects into the resonators. Input grid sections 87 and 88, and output grid sections 89 and 91 are transversely or radially aligned. The cathode and resonator arrangement are enclosed in an evacuated envelope as in Fig. 1.

Suitable individual tuning means 90 and 90', similar to that at 46 in Fig. 1, are provided for resonators 84 and 85. Concentric antenna line connections 92' and 93' individual to resonators 84 and 85 are also provided, enabling the device to be used as an oscillator when they are interconnected. The interior of Fig. 4 has the same water-cooled collector electrode 53 as in Fig. 1, and also has the same grid 48 and heat radiant fins 51 for suppressing secondary electron emission as in Fig. 1. Otherwise the device of Fig. 4 has the operation above explained.

Fig. 5 illustrates diagrammatically a section through the axis of a hollow resonator velocity modulation device having but a single electrode gap and a reflector for returning velocity grouped electrons through the gap.

Annular cathode 21 surrounds a hollow conductive member 92 which is preferably in the form of an annulus of revolution about axis A—A. Grid electrodes 93 and 94 are provided in alignment on the outer cylindrical wall 95 and on the reentrant annular pole 96. An annular reflector having a continuous radially outwardly facing reflecting face 97 is suitably mounted to locate face 97 in proper location.

Electrons in the radially directed annular beam emitted from surface 22 are alternately retarded and accelerated in passing through the gap between electrodes 93 and 94 so that they become velocity-grouped by the time they are returned by reflector 97 back through the electrode gap. As the velocity-grouped electrons return through the gap between electrodes 94 and 93 they are in condition to give up energy to the field. Since these general principles of reflex operation are known, further detail is unnecessary. This embodiment as described demonstrates application of the invention to velocity modulation devices of the reflex type.

Fig. 6 is similar to Fig. 5 but illustrates a reflex device wherein the resonator shell 98 is of somewhat different shape, being a figure of revolution of the illustrated cross-section. Here grids 99 and 100 are aligned on the inner peripheral wall of hollow body 98 and the end of inwardly projecting reentrant annular pole 101, and reflector 102 is a relatively slender annulus suitably supported opposite grid 99. Annular cathode 103 is smaller than cathode 22, being suitably mounted close to grid 100. The operation of the device of Fig. 6 is similar to that of Fig. 5.

Fig. 7 illustrates another velocity modulation device according to the invention wherein the generally annular resonator body 104 comprises a figure of revolution of a simple hollow resonator body of the frusto-conical cross-section illustrated, about the axis B—B. Entrance and exit grid electrodes 105 and 105', respectively, are formed in the cylindrical walls of body 104, in radial alignment with annular cathode 21 and an annular collector electrode 106.

Similarly Fig. 8 illustrates a further simple single chamber resonator body 107 formed by revolution of the generally frusto-conical cross-section illustrated, about axis B'—B'. Annular cathode 108 is supported centrally in an opening of a cylindrical annular electrode 109 insulated from body 107 by the insulating annulus 110 which also seals the opening 111 in the outer wall of the resonator body. The oscillating circuit is provided by the two opposed electrodes comprising electrode 109 and the bottom wall 112 of body 107. A coupling loop 113 is disposed inside the resonator and adapted for extraction of energy as desired.

Figs. 7 and 8 therefore illustrate application of the invention to the type of velocity modulation device disclosed in United States Letters Patent No. 2,269,456 issued January 13, 1942, to Hansen et al., and reference is made to that patent for further details of common operation. The general structure of these two figures is broadly covered in copending application, Serial No. 474,621, filed in the name of Russell H. Varian.

As many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. An ultra high frequency device comprising a substantially annular hollow resonator having a wall provided with an electron-permeable section, said resonator having an interior hollow member surrounding a field-free electron drift space; said hollow member being surrounded by

the electromagnetic field space of said resonator, and a cathode having an electron emission surface surrounding said resonator adjacent said electron-permeable section, electrons from said cathode after passing through the electron-permeable section of said resonator becoming velocity modulated within said resonator and before entering said interior hollow member, said hollow member having an electron-permeable section to admit the electrons therein to enable grouping of the electrons within said hollow member, said hollow member having a second electron-permeable section enabling the passage of the grouped electrons back into said resonator for effecting an interchange of energy with the electromagnetic field thereof.

2. An ultra high frequency device comprising, a substantially annular hollow resonator adapted to have an oscillating electromagnetic field established therein, a cathode having an electron emissive surface surrounding said resonator and adapted to project electrons into said resonator and through such field, a hollow interior member contained within said resonator and completely surrounded by the field space of said resonator and providing a field-free drift space for electrons, and means for collecting electrons located radially inwardly of said resonator, said electron collecting means having means for dissipating secondary emission electrons.

3. An ultra high frequency device of the velocity modulation type comprising, hollow annular resonator means having an outer annular wall and an inner annular wall located radially inwardly of said outer wall, said resonator means being provided with transverse openings in its outer and inner annular walls, cathode means located exteriorly of said resonator means for directing a stream of electrons radially inwardly through said openings, and an interior hollow member providing a field-free drift space for the stream of electrons, said interior hollow member having an electrode projecting outwardly therefrom opposing the inner wall of said resonator for forming therewith a condenser for increasing the capacity of the resonant circuit of the resonator thereby providing considerable effective capacitance at said electrode.

4. High frequency electron discharge apparatus comprising a source of electrons, a cavity resonator having an outer enclosing wall adjacent said source and a hollow body supported therewithin, said wall and hollow body having electron-permeable portions defining a pair of electron-permeable gaps, voltage accelerating means electrically connected with said electron source and said resonator for projecting a stream of electrons from said source successively through said gaps, means positioned in the path of said electrons exteriorly of said resonator for collecting said stream of electrons after passage through said gaps, and suppressor means surrounding said collecting means for preventing return of secondary electrons from said collecting means to said resonator.

5. Apparatus as in claim 4, wherein said suppressor means comprises a grid interposed between said resonator and said collecting means, and means electrically connecting said grid to said source.

6. Apparatus as in claim 4, wherein said collector means comprises a series of conductive members substantially parallel to said electron stream for minimizing secondary electron emission and providing increased surface area for heat dissipation.

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