VELOCITY MODULATION ELECTRON DISCHARGE DEVICE

Filed Nov. 16, 1946

Fig.1.

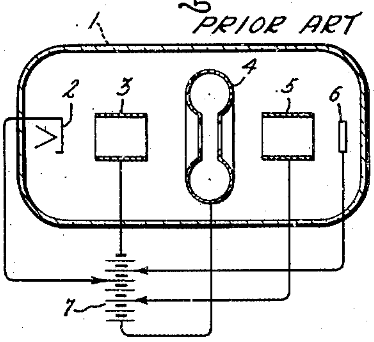



Fig.2.

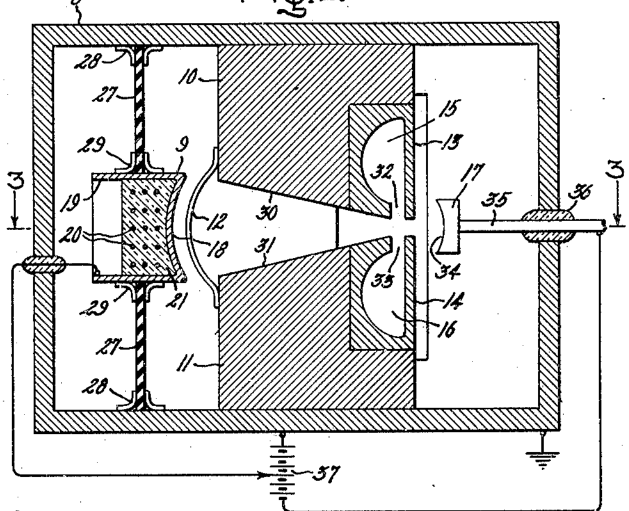


Fig.3.

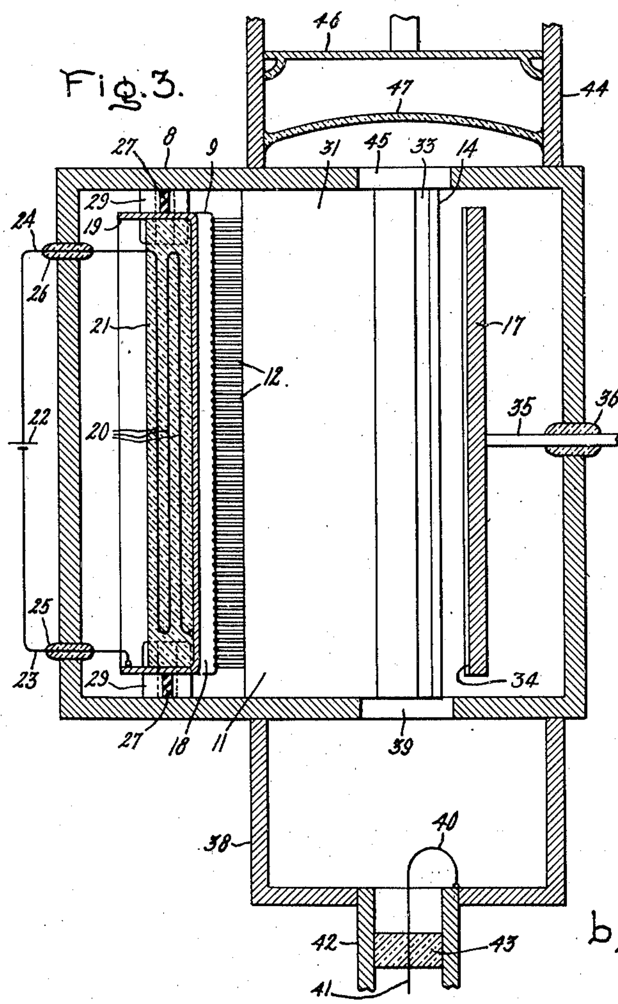
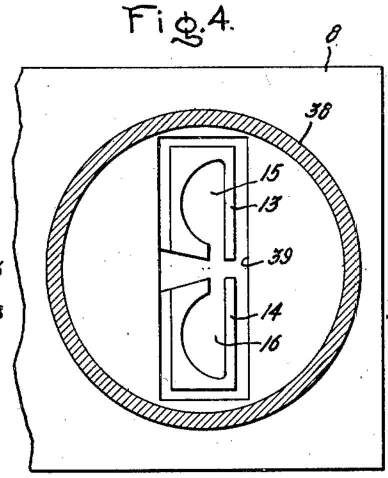


Fig.4.



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# UNITED STATES PATENT OFFICE

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## VELOCITY MODULATION ELECTRON DISCHARGE DEVICE

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3 Claims. (Cl. 250—27.5)

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This invention pertains to electron discharge devices, such as oscillators, amplifiers, or the like, employing a velocity modulated beam of electrical particles and has for its object the provision of an improved construction capable of substantially greater power output and substantially higher frequency than devices of the type hitherto known in the art.

For various usages in the high frequency electrical arts, such as for the purpose of generating or amplifying high frequency oscillations, there have been developed, in recent years, numerous electron tube constructions employing the principle of velocity modulation of an electron beam for example constructions in which a moving electron beam having induced periodic density variations along its length is caused to pass in the vicinity of a resonant circuit element, such as a cavity resonator, in such manner that the density variations will induce and sustain oscillations in the resonant element. Such constructions have not been as satisfactory as could be desired for the aforesaid purposes principally because the maximum power output and the maximum frequency obtainable have not always been sufficient to satisfy the progressively increasing demands of the art for generators and amplifiers of the highest possible power output and highest possible frequency. I have found that any such shortcomings may be attributed largely to restrictions on the size and density of the electron beam imposed by the geometrical configurations of the various electrodes and resonant circuits heretofore employed. For example, in the constructions heretofore common in the art, an electron beam of generally circular cross section emanates from a cathode of similar cross section and passes axially through toroidal cavity resonators forming the resonant circuit element of the device, the construction therefore being symmetrical with respect to the axis of the electron beam. Since, for a given electron beam voltage, the amount of power which can be obtained from the device is limited by the amount of electron beam current which can be passed through the cavity resonator, and since that current is in turn limited by the maximum current density which may be derived from the surface of the cathode used in the electron gun from which the beam emanates, such axially symmetrical arrangements impose geometric limitations on the net power output. Therefore, it becomes desirable not only to provide a cavity construction which will permit a much greater amount of electron current to flow past the cavity

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resonator to be excited but also to provide a cathode construction which will permit the use of an active cathode surface of maximum area in order that the maximum current density obtainable from such area will not in itself act to limit the total amount of current in the beam.

In accordance with my invention there may be provided a construction which obviates the aforementioned limitations to a considerable degree. Generally speaking, the objects of the invention are accomplished by constructing the discharge device in such a manner that the geometry of the electrodes, the cavities and of the beam is symmetrical with respect to an extended plane rather than to the axis of a narrow electron beam as in the constructions heretofore known. For example, the various elements of the device may be so constructed that the electron beam produced is in the shape of a flat wedge or sheet having considerable planar area with the resonant cavities themselves positioned on opposite sides of the plane of the beam. Such geometry permits of the use of an electron beam having considerably greater total current because the beam is extended over a considerable area. At the same time it permits the use of a cathode of extended active surface area corresponding to the cross section of the wedge shaped electron beam.

The features of the invention desired to be protected are set forth in the appended claims. The invention itself together with further objects and advantages thereof may be best understood by reference to the following specification when taken in connection with the accompanying drawing in which Fig. 1 is a schematic illustration of the construction heretofore common in the art; Fig. 2 represents in cross section an electrical discharge device embodying the principles of the invention; Fig. 3 represents in cross section a view of the device taken along the line 3—3 of Fig. 2; while Fig. 4 represents a view of the device of Fig. 2 looking from the output connections into the cavity resonator section of the device.

In Fig. 1 there is shown for purposes of illustration a velocity modulated electron discharge device of the reflex type which may include within an evacuated envelope 1, a cathode 2 having the usual disk shaped active surface, a cylindrical focusing electrode 3, a cavity resonator in the form of a toroidal cavity 4 having a central aperture therethrough, a second cylindrical focusing electrode 5, and a reflecting anode 6. As is well understood in the art, a narrow electron beam of circular cross section may be caused to pass from the cathode 2 through the electrode 3, the cavity 4, the second focusing electrode 5 whereupon it is reflected by the anode 6 back through the central aperture in the cavity 4, whereupon it will excite resonant oscillations within the cavity 4. It will be understood, of course, that periodic density variation lengthwise of the beam will be induced in the beam after its first passage through the cavity 4 and that such density variation will sustain oscillations within the cavity 4 during the return of the beam to the cavity on its reversed motion. To effect such behavior appropriate electrostatic potentials may be applied to the various electrodes by any suitable means such as the battery 7 which, by means of the connections indicated, imposes with respect to the cathode a high positive potential on the cavity 4, a negative potential on the focusing electrode 3, a negative or slightly positive potential on the focusing electrode 5 and finally a negative potential on the reflecting anode 6.

It will be apparent that all of the various electrode elements and the cavity 4 are symmetrical about the axis of the electron beam and concentric therewith. Under such circumstances the amount of power which may be derived from the cavity 4 will be dependent upon the total amount of electron current which can be passed through its central aperture by the beam and, moreover, the total amount of current which can be gotten into the beam will be limited by the maximum current density obtainable from the active surface of the cathode 2. It will be understood that these limiting conditions are equally applicable to velocity modulation tubes of other than the reflex modulation type, for example those in which the density variations of the electron beam induce oscillations in a second cavity resonator similar to resonator 4 but positioned farther along the beam path.

Although it will be understood that the principles of the invention are applicable to all types of velocity modulation discharge devices, there is shown in Figs. 2 and 3, as one illustration of the inventive principles, an electron discharge device of the velocity modulation type employing reflex principles. The device shown may comprise generally a preferably metallic hermetically sealed envelope 8 in the form of a parallelepiped or other geometrical shape having considerable extension in one plane such as the plane of Fig. 3. Within the envelope 8 there is provided a cathode 9, an accelerator anode structure comprising the symmetrically positioned blocks 10 and 11 provided with a focusing grid comprising parallel wires 12, a cavity resonator structure comprising the blocks 13 and 14 mounted integrally within the corresponding blocks of the accelerator electrode and having cavities 15 and 16 formed therein, and a reflecting electrode 17. As indicated more clearly in Fig. 3 all of these elements will have considerable extension in the direction perpendicular to the plane of Fig. 2, for example they will be elongated to extend completely across the width of the envelope 8.

The cathode 9 may comprise any suitable structure which presents to the accelerator anode structure a concave cylindrical sector portion 18 capable of focusing electrons emanating from a thermionically active coating on the surface of portion 18 into the accelerator anode slot formed by the opposing surfaces of blocks 10 and 11. For example, it may comprise the box-like structure 19 having the concave cylindrical sector portion 18 as an end wall facing the accelerator anode structure. The surface of portion 18 may be coated with any of the suitable thermionically emissive substances known in the art. Any suitable means for raising that surface to an electronically emissive temperature may be provided such as the heater wires 20 embedded within a ceramic or other insulating material 21 within the interior of the box-like structure 19 of the cathode. Suitable means for energizing the said heater wires may be provided such as a battery 22 connected to the heater by the externally accessible leads 23 and 24 extending through and insulated from the envelope by hermetic sealing beads 25 and 26 of glass or like material. The cathode may be supported in insulating relationship to the envelope 8 by any suitable means such as the insulating wall 27 affixed to the envelope 8 by means of the metallic clamps 28 spot welded or otherwise affixed to envelope 8. The cathode 9 may be supported within suitable slots in the insulating wall 27 and rigidly affixed thereto by metallic clamps 29 spot welded or otherwise affixed to structure 19.



The blocks 10 and 11 comprising the accelerator anode structure may be directly affixed to the wall of envelope 8 in conducting relationship therewith by any suitable means such as by brazing or welding thereto. Since the major portion of the energy losses dissipated as heat by the device is dissipated in these accelerator anode blocks and the cavity blocks 13 and 14, the construction indicated is particularly advantageous in that heat may be directly conducted to the metallic envelope 8 and thereby dissipated externally in order that the electrode structure may not operate at too high a temperature. The focusing grid wires 12 may each be conductively affixed at their opposite ends to one of the anode blocks 10 and 11 and formed in a generally arcuate shape conforming closely to and generally concentric with the concave shape of the cathode. In order to provide optimum electron beam focusing effects by the grid wires, it is preferable that the spacing between wires 12 be small in relation to the distance from the grid wires to the cathode surface. For example, the distance between any two wires 12 is preferably less than one half the distance from those wires to the cathode surface. While these grid wires are indicated as preferably being parallel to each other in order that parallel interstitial spaces may be presented to the electron beam, it will be understood that this grid structure may be also formed of a mesh of mutually perpendicular wires in the manner of grid constructions known in the art. The dimensions of the interstitial space should however, be small by comparison with the distance from the grid to the cathode for optimum focusing effects. The opposed surfaces of the anode blocks 10 and 11 will preferably be formed in such manner as to present a generally wedge shaped opening between the blocks formed by the opposing surfaces 30 and 31. As is well understood in the art appropriate shaping of these surfaces as well as the concave surface of the cathode will result in desired shaping of electron beam configuration.

The cavity blocks 13 and 14 may be formed by any construction which presents cavities of the desired configuration necessary to oscillate at the desired frequencies. For example, they are shown as comprising blocks having cavities of semi-circular cross section extending laterally to the envelope and having laterally extending gaps 32 and 33 juxtaposed to the electron beam thereby forming an opening for communication between the space in the cavities 15 and 16 and the regions of the electron beam. If desired such cavity constructions may be formed by laminated stamped sheets each having the desired cavity shape.

The reflecting anode 17 may comprise any suitable form which presents a concave surface 34 adapted to reflect and focus the electron beam back into the vicinity of the cavity gaps 32 and 33. For example, it is shown as comprising a bar extending laterally to the envelope and having a cylindrical concave surface formed in the side presented to the cavity resonators. That electrode or anode may be supported in insulating relationship to the envelope 8 by any suitable means such as the rod 35 welded thereto and extending through the glass sealing bead 36 in the envelope wall.

It will be apparent to those skilled in the art that when suitable potentials corresponding to those imposed on corresponding electrodes of velocity modulation devices heretofore known are applied to the various electrodes described above, a thin substantially wedge shaped electron beam having substantial extended area in a direction transverse to the direction of motion of its electron particles will be formed along a path extending from the cathode through the opening in the anode structure and past the cavities toward the reflecting anode. Thereupon it will be reflected back into the vicinity of the cavity along its entire width. By means of reflex velocity modulation principles, oscillations will thereby be induced in the cavity blocks. For the purpose of applying those potentials any suitable means may be employed such as the battery 37 which imposes with respect to the cathode, a relatively high positive voltage upon the accelerating anode structure and a negative voltage on the reflecting anode.

For the purpose of extracting useful energy from the cavities or for the purpose of introducing energy for amplification or like purposes, any suitable means may be provided. For example, suitable coupling loops may be inserted within the cavity and attached to appropriate external coupling lines. Alternatively, a wave guide may be coupled to the cavities through an iris or slot formed in the wall of the envelope adjacent to one end of the cavities. Such a means is shown for example in Fig. 3 and comprises a cylindrical wave guide or cavity resonator 38 hermetically attached to the external surface of the wall of the envelope 8 which has an appropriate slot-like opening 39 exposing the ends of the cavities to external view as indicated in Fig. 4. A suitable coupling loop 40 connected to the closed distal end of the cylindrical wave guide 38 and to the inner conductor 41 of a coaxial transmission line comprising the inner conductor 41 and the outer conductor 42 may be provided for delivering energy derived from the wave guide to suitable external utiliziation circuits not shown. For the purpose of maintaining hermetic sealing of the discharge device at these output connections, the coaxial transmission line may be hermetically sealed by a bead 43 of glass or like vitreous material sealed across the outer conductor 42.

The resonant frequency of the cavities may be controlled and tuned by a cylindrical wave guide or cavity resonator 44 of variable length attached to the opposite wall of the envelope and juxtaposed to the other end of the cavities through an iris or slot 45 cut into the wall of the envelope at that point in a manner similar to that of the slot 39. The length of this cylindrical wave guide may be controlled and varied by means of the piston 46. In order to maintain the hermetic sealing of the device at this point of connection between the wave guide 44 and the envelope, the glass window 47 may be provided across the cross section of the cylindrical wave guide and hermetically sealing the same. It will be understood that movement of the piston 46 in either direction will result in a corresponding change in the inductive or capacitative properties of the cavities and thereby result in a desired change in frequency. Alternatively, the cavities may be provided with a tuning system similar to that shown and claimed in my copending application Serial No. 720,250 filed January 4, 1947. In the latter case the accelerating anode and resonators will be formed by a laminated construction in the manner shown in the mentioned application.

In order that the device may operate at optimum efficiency it is preferable that the wave guide-like structure formed by cavities 15 and 16 operate near its cutoff wave length so that the phase wave length along the longitudinal direction of the structure is long. The length of the cavities 15 and 16 is then only a small fraction of phase wave length and as a result the high frequency electric field across the gaps 32—33 maintains a high percentage of its maximum value at the center along the entire length of the cavities. For example if the cavity section 15—16 is made 70 electrical degrees in length and sections comprising guides 38—44 are 55 electrical degrees each, the electric field at the ends of the gaps 32 and 33 only drop to 82 per cent of the maximum value at the center.

While I have shown and described a particular embodiment of my invention, it will be obvious to those skilled in the art that various changes and modifications may be made without departing from my invention in its broader aspects and I, therefore, aim in the appended claims to cover all such changes and 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 electrical discharge device of the reflex velocity modulation type comprising a pair of spaced cavity resonators, an elongated anode structure extending between said resonators, said anode structure having extending therethrough a longitudinally extending cavity resonator symmetrical relative to a longitudinal axis thereof and tuned along with said pair of resonators to the frequency of oscillation of said device, said anode structure also having a transverse passageway with an elongated cross section extending therethrough in a plane perpendicular to the axis of said last-mentioned resonator and communicating with said last-mentioned resonator, and means for directing a relatively wide and thin electron beam through said passageway to excite said resonators at said frequency comprising an elongated cathode and an elongated reflector electrode disposed on opposite sides of said anode structure and disposed substantially in the plane of said passageway.

2. An electrical discharge device of the reflex velocity modulation type comprising a pair of spaced cavity resonators, an elongated anode structure extending between said resonators, said anode structure having extending therethrough

a longitudinally extending cavity resonator symmetrical relative to a longitudinal axis thereof and tuned along with said pair of resonators to the frequency of oscillation of said device, said anode structure also having a transverse passageway with an elongated cross section extending therethrough in a plane perpendicular to the axis of said last-mentioned resonator and communicating with said last-mentioned resonator, means for directing a relatively wide and thin electron beam through said passageway to excite said resonators at said frequency comprising an elongated cathode and an elongated reflector electrode disposed on opposite sides of said anode structure and disposed substantially in the plane of said passageway, and means for varying the resonant frequency of said cavity resonators comprising a tuning plunger movably mounted in one of said pair of cavity resonators.

3. An electrical discharge device of the reflex velocity modulation type comprising a pair of spaced cavity resonators, an elongated anode structure extending between said resonators, said anode structure having extending therethrough a longitudinally extending cavity resonator symmetrical relative along with said pair of resonators to a longitudinal axis thereof and tuned to the frequency of oscillation of said device, said anode structure also having a transverse passageway with an elongated cross section extending therethrough in a plane perpendicular to the axis of said last-mentioned resonator and communicating with said last-mentioned resonator, and



means for directing a relatively wide and thin electron beam through said passageway to excite said resonators at said frequency comprising an elongated cathode and an elongated reflector electrode disposed on opposite sides of said anode structure and disposed substantially in the plane of said passageway, the phase wave length of said last-mentioned resonator being of the order of 70 electrical degrees and the phase wave length of each of said pair of resonators being of the order of 55 electrical degrees whereby the high frequency electric field across said last-mentioned resonator where said passageway communicates with said last-mentioned resonator is a high percentage of its maximum value along the length thereof and efficient density modulation of said electron beam is obtained along its entire width.

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