

March 31, 1942.

J. A. MORTON

2,278,210

ELECTRON DISCHARGE DEVICE

Filed July 5, 1940

2 Sheets-Sheet 1

FIG. 1

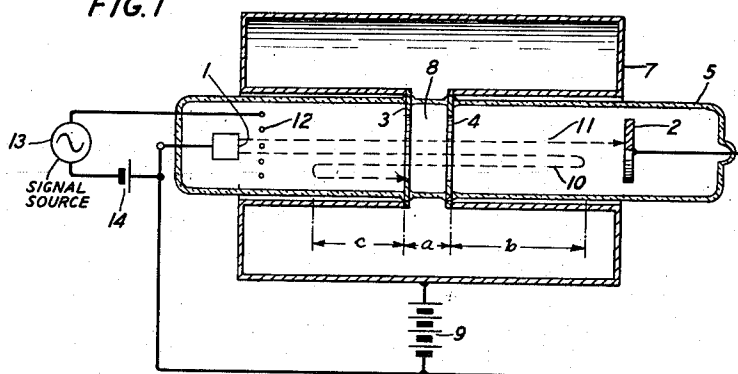


FIG. 2

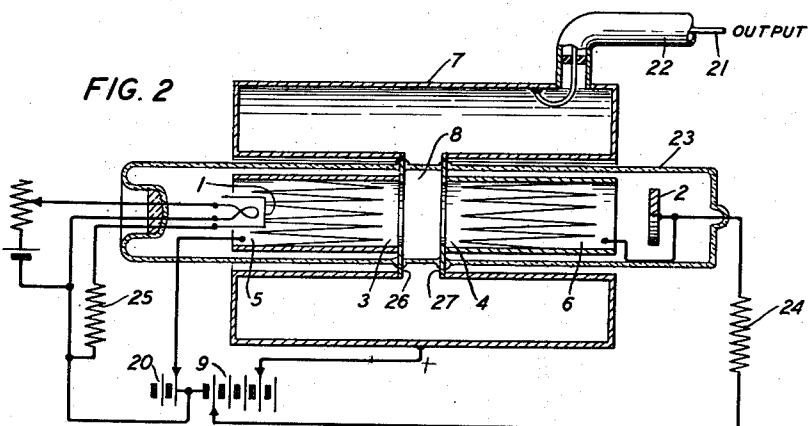
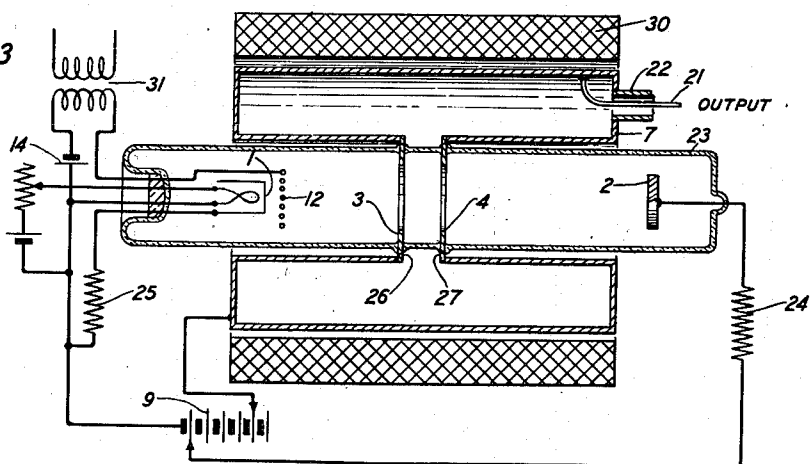


FIG. 3



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FIG. 4

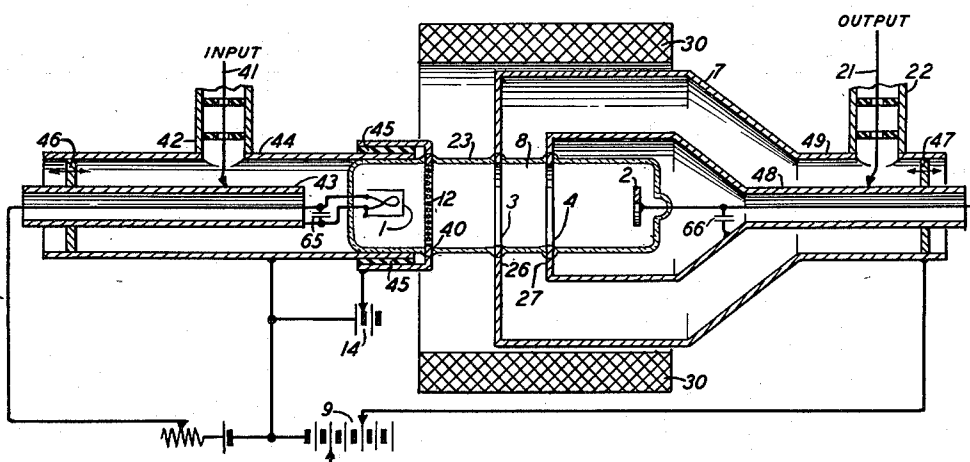
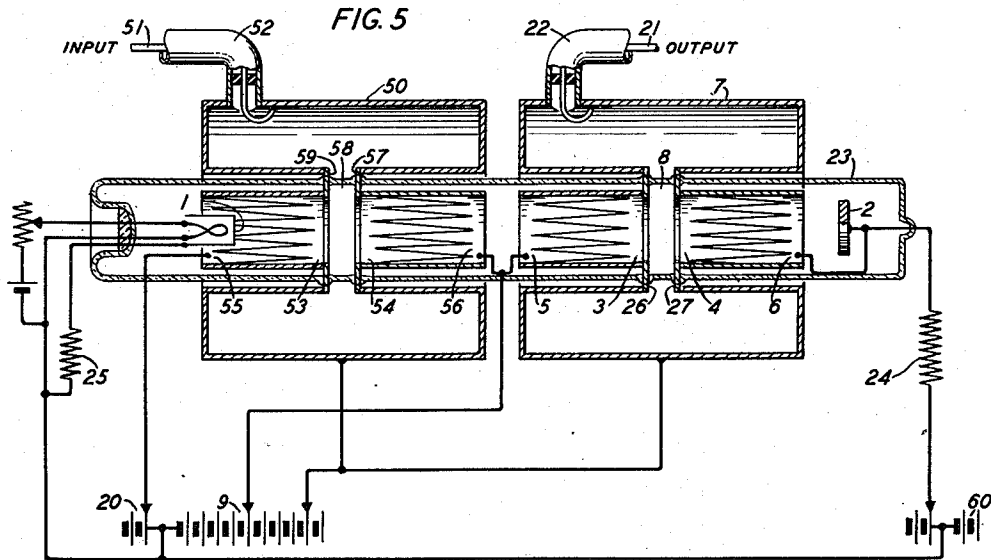


FIG. 5



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2,278,210

ELECTRON DISCHARGE DEVICE

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Application July 5, 1940, Serial No. 343,986

18 Claims. (Cl. 179-171)

This invention relates to electron discharge devices and particularly such devices used for the purpose of generating high frequency electrical energy through interaction between moving electrons and a high frequency electric field.

An object of the invention is to provide such a device which is operable with relatively small electron currents and low field intensities.

Another object is to provide such a device in which the operating conditions are not severely critical.

Additional objects are to provide in such a device particular adaptability to the production of very high frequency energy and to utilize therewith efficient non-radiating high frequency circuits.

A familiar type of high frequency generator is one known as the Barkhausen oscillator. In this device electrons are caused to oscillate back and forth between the electrodes of a vacuum tube and thereby generate high frequency energy in an attached electrical circuit. This arrangement is subject to several limitations among which are those of upper frequency limit and maximum power output. Some of the more recent types of high frequency generators employ means for introducing variations of velocity into a steady stream of electrons so that after drifting or being acted upon by a sorting means which is effective because of the different velocities of the electrons the stream becomes made up of more or less distinct groups of electrons which are then caused to pass through a high frequency electric field in the proper phase to deliver energy to it at the frequency of the velocity variations. Devices of this type have been described by Messrs. W. C. Hahn and G. F. Metcalf in the Proceedings of the Institute of Radio Engineers, volume 27, February 1939, pages 110 to 116, and by Messrs. R. H. Varian and S. F. Varian in the Journal of Applied Physics, volume 10, February 1939, page 140. The efficacy of these devices depends to a great extent upon the magnitude of the electron current, the strength of the high frequency electric fields at the points of interaction with the electron stream and the accuracy of adjustment.

The present invention, incorporating electron beam forming electrodes, cavity resonators and field free spaces over portions of the electron path, overcomes limitation of the types of devices just referred to and secures advantages in ease and efficiency of operation. Advantages over the Barkhausen type of device result from the possible increased size of tube and electrodes

for a given frequency of operation, the use of a non-radiating resonant cavity as the oscillatory circuit and the utilization of field free spaces to increase the ratio of electron period to high frequency field period. Advantages over the usual velocity variation type of device result because the increased number of interactions between the electrons and the high frequency field permits the use of lower electron current and high frequency field intensities and makes less essential the sharp grouping of electrons. The methods of obtaining the desired objectives will be apparent from the following detailed description and the illustrative embodiments shown in the accompanying drawings.

In the drawings:

Fig. 1 is a simplified drawing to illustrate the underlying principles of the invention;

Fig. 2 illustrates an oscillator utilizing a cavity resonator as the high frequency circuit and composite electrodes for accelerating and focusing the electron stream;

Fig. 3 is similar to Fig. 2 but showing a different type of accelerating electrode in combination with a direct current field for focusing the electron stream, also including the control grid for modulating or amplifying purposes;

Fig. 4 shows an alternative method of connecting to the control grid which is more suitable for a high frequency amplifier arrangement than the arrangement illustrated in Fig. 3 as well as a different type of resonator and output connection; and

Fig. 5 shows an amplifier arrangement utilizing two cavity resonators and composite type accelerating and focusing electrodes.

Fig. 1, which is a simplified sketch intended only to illustrate the principle of operation, shows in axial section a cavity resonator 7, an electron emitting cathode 1 and a collector 2. The cavity resonator is of the reentrant type and is connected to the ring electrodes 3 and 4 sealed into the evacuated envelope 5, as indicated. The resonator is charged to a positive potential with respect to cathode 1 and collector 2 as shown by battery 9 so that the inner ring electrodes 3 and 4 on each side of gap 8 serve as accelerating electrodes which, in cooperation with the more negatively charged electrodes 1 and 2, tend to move electrons which are in the space between 1 and 2 toward the gap 8.

In operation, a steady stream of electrons is emitted from cathode 1 and is accelerated to the right toward gap 8 and collector 2. At gap 8 over the distance a the high frequency electric

field due to the current assumed to be flowing in the resonator 7 is encountered. Electrons entering this field during one phase of the cycle are retarded and give up energy to the resonator 7 while those entering the field during the opposite phase will receive energy and be accelerated. Having passed to the right of gap 8 all of the electrons will be subjected to the repelling force of the negative electrode 2, or it may be said that the field set up by the positive electrode 4 and the negative electrode 2 tends to move the electrons back to the left toward gap 8. Electrons which have been accelerated sufficiently will in spite of the retarding field reach electrode 2 and be collected. Electrons which have given up energy and been retarded in gap 8 will not reach 2 but will be reversed and accelerated to the left traversing the path portion b then passing through the high frequency field at gap 8 a second time in the proper phase to give up energy. Passing on to the left after passing 8 these electrons encounter the field produced by the positive electrode 3 and the negative cathode 1 which tends to move the electrons back again to the right causing them, after traversing the path portion c, to pass through the high frequency field at 8 a third time to deliver energy to the resonator. Thus the useful, energy-giving electrons may pass back and forth through the high frequency field at gap 8 many times before losing sufficient velocity to be finally collected at either electrode 3 or 4 as indicated by the broken line 10 which shows the type of path followed by these electrons. The non-useful electrons, which absorb sufficient energy during the first transit of gap 8 to reach collector 2 follow a path such as is indicated by the broken line 11. Since these are immediately collected whereas the useful, energy-giving, electrons pass through region a, at gap 8, many times there is a preponderance of energy-giving electrons crossing the gap 8 and high frequency energy is thereby generated by the resonator 7.

The proper operating conditions are obtained by adjusting the electrode potentials so that the complete vibration period of the electrons is approximately $(2n-1)T$ where $(n=1, 2, 3, \text{etc.})$, and T is the period of the resonant cavity. Also the transit time across the gap, or through distance a should be less than $\frac{1}{2}T$.

Since the vibration period may be a multiple of the period of the resonant cavity and thus relatively long, it is apparent that possible dimensions of tube structures are not greatly restricted. This situation is favorable to the construction of tubes for high frequency operation since the dimensions can be large enough to permit easy construction, efficient high frequency design and high heat dissipating ability.

The control grid 12 shown adjacent to the cathode 2 is an adjunct which may be included in devices of this type and will be referred to again in connection with later figures. This grid is not essential to the production of oscillations in the high frequency circuit but may be used for control and amplification purposes. It has proved useful in controlling oscillation production through variation of the bias potential between it and the cathode and by impressing alternating potentials upon the grid from a source such as 13 the output of the oscillator may be amplitude modulated. It is also possible if the frequency of source 13 is the same as that of the cavity resonator 7 to utilize the grid 12 as a control element and operate the device as an ampli-

fier. In this case one method of operation is to adjust the electrode voltages so that without high frequency input, though electrons traverse the tube, the conditions are not such as to permit self-oscillation.

It will be remembered from the description of operation as a generator that oscillations are maintained through the mechanism of plate sorting wherein the plate, electrode 2, collects the electrons which have crossed gap 8 in a phase of the high frequency field to absorb energy from it and be accelerated, thus eliminating the non-useful electrons. This process involves adjusting the potential of electrode 2 so that electrons which are positively accelerated by the high frequency field are collected while the energy-giving electrons which are retarded by the high frequency field are turned around and returned through the field to again transfer energy to it. If now the potential of collector 2 be made more negative increasing its reflecting power to where it is not possible for electrons to be collected, no oscillations will occur. However, if a high frequency signal is then applied to the grid, the charge density of the electron stream will be varied so that a preponderance of favorable electrons will exist thus inducing a field in the cavity resonator dependent upon the amount of density variation and hence upon the input. By biasing the control grid corresponding to obtain what is commonly termed class "C" or "B" operation, more efficient operation and higher power gain may be obtained. This suggests that by now feeding back from output to input under class "C" bias a more efficient generator may be produced since all electrons may then be in groups which have optimum phase relative to the high frequency field in the gap of the resonator. Such an arrangement may be developed from Fig. 4 by simply connecting the output and input coaxial lines together through such a length of line that a cooperative phase relation exists between the input and output high frequency voltages.

Fig. 2 shows in more detail than Fig. 1 a practical oscillator circuit embodying the principles of the invention. Here sealed into the evacuated envelope 23 of the electron gun are two rings of conducting material, 26 and 27, to which are connected, external to the envelope, the cavity resonator 7 and inside the envelope the portions 3 and 4, of composite accelerating electrodes 3, 5 and 4, 6. Composite electrodes of this type are described in copending application No. 290,387 of F. B. Llewellyn and copending application No. 290,359 of F. Gray. The gap 8 where the high frequency field of the resonator 7 is exposed to interaction with the electron stream is, then, within the tube between the rings 26 and 27 and between adjacent ends of the composite accelerating electrodes which are connected to those rings. These composite electrodes extend along the electron path between cathode 1 and collector 2, one surrounding a portion of the electron path on each side of the gap 8. Each of these electrodes is made up of two interleaved portions of conducting material surrounding the electron path and insulated from each other. The relative areas of surface of the two portions of conducting material exposed to the electron stream vary along the direction of the electron path, the exposed areas of the two portions preponderating in opposite directions so that when maintained at different potentials a uniform axial field is produced in a direction depending upon the relative polarities of the two portions. The portions

3 and 4 are connected to the polarizing potential source 9 to be at a higher potential than the portions 5 and 6 so that the accelerating fields of both 3, 4 and 4, 6 are directed toward the gap 8 where the high frequency field of the resonator is exposed to the electron stream.

The composite accelerating electrode structure lends itself to design variations to improve the efficiency of the device through contributing to the constancy of the vibration period of the electrons over a range of amplitudes. Such design involves varying the shapes of the two interleaved portions of material making up an electrode, as explained in the compending application Serial No. 290,359 of F. Gray, so that the relative areas of surface exposed to the electron stream vary from point to point along the axis of the electrode and so along the electron path in such a manner that the accelerating field and so the forces on the electrons at different points along the path are such as to tend to equalize the periods of vibration of the electrons even though vibrating over paths of different lengths. This is a refinement of design, however, which is not essential to operation.

As in Fig. 1, the electron stream originates at the indirectly heated cathode 1, the non-useful electrons are collected at collector 2 and the useful electrons are finally collected at electrode portion 3 or 4. Collector 2 is polarized negatively with respect to electrode portions 3 and 4. It is shown in Fig. 2 connected to electrode portion 6 which, however, is not essential as a difference of potential between 2 and 6 may be employed. A source 20 is shown to provide a potential difference between the cathode 1 and electrode portion 5 to assist in focusing the electron stream. The resistors 24 and 25 are included in the cathode and collector leads to prevent spurious oscillations. They are relatively high in value, not less than 100 ohms.

The operation of this circuit is as was described in connection with Fig. 1 the electrons being caused to vibrate along the axis of the gun through the field at gap 8, delivering high frequency energy to the resonator 7, the electrode potentials being adjusted so that the vibration period of the electrons is an odd multiple of the period of the resonator.

One method of taking high frequency energy from the resonator is to connect a coaxial line as shown at the point designated "output" where 21 and 22 represent the inner and outer conductors, respectively. A different method of connecting the resonator to an output circuit is shown in Fig. 4.

In Fig. 3 is shown in axial section an alternative form of construction of a device according to the invention including also the grid for modulating and amplifying purposes previously referred to in connection with Fig. 1. Here the accelerating electrodes 3 and 4 are the internal portions of the rings 26 and 27 which are sealed into the glass envelope 23 of the electron gun which are connected, external to the envelope, to the resonant cavity 7. As before, the point of interaction between the electron stream and the high frequency field of the resonant cavity is the gap 8 between the electrodes 3 and 4 within the envelope. The electromagnet 30 provides an axial magnetic field to maintain the focus of the electron stream between cathode 1 and collector 2. As explained in connection with Fig. 1 the useful, energy-giving, electrons do not go to collector 2 but vibrate back and forth past the gap

8 contributing high frequency energy to the cavity 7 during each traversal of the gap and are finally collected at electrodes 3 and 4. Except for effects of the magnetic field upon the electron trajectories the operation of Fig. 3 is as described in connection with Fig. 1.

Elements of this drawing having the same designations as on previous drawings have the same functions as in the previous drawings. The grid 12 is shown connected to transformer 31 to illustrate a means of modulating the high frequency energy generated in the resonant cavity.

Fig. 4 is broadly similar to Fig. 3 but shows a different structure of grid 12 and method of operating grid 12 which are more suited to high frequency amplifier applications than the arrangement of Fig. 3 which is appropriate for low frequency modulating purposes. It also shows an alternative structure of the cavity resonator such that its frequency of operation is variable and facilities are provided for matching to the load or output circuit. In Fig. 4 the grid 12 is supported in the electron gun on a ring 40 sealed into the glass envelope in the same manner as rings 26 and 27 in Fig. 2 and Fig. 3. Connected to this ring 40 external to the envelope, through the capacitance of the insulating sleeve 45, and thereby to the grid 12, is the outer conductor 44 of a coaxial line the other conductor 43 of which is connected to the cathode. This line 43, 44 is connected through the coaxial line 41, 42 to a source of high frequency to be amplified and for which the cavity 7 is resonant. The coaxial line 43, 44 is terminated by a closing and short-circuiting member 46 which is movable to permit tuning of the line to obtain maximum voltage between the grid 12 and the cathode 1. The conductor 41 of the input line may be connected at a point along conductor 43 appropriate for impedance matching. The grid 12 is insulated for direct current from conductor 44 and the cathode 1 connected thereto through 46 and 43 to permit inserting a bias potential from source 14. The capacitance from ring 40 to 44 through the insulating sleeve 45 interposes negligible impedance to the high frequency excitation voltage. The cavity resonator 7 is shaped a little different from the showing in Fig. 3 and is supplemented for tuning by the adjustable portion of coaxial line 48, 49. This line is closed by the movable short-circuiting member 47 whereby the resonator may be tuned to different frequencies. The inner conductor 21 of the output line may be connected at a point along conductor 48 appropriate for impedance matching. The resonant cavity 7 is attached to rings 26 and 27 which are sealed into the glass envelope and form inside the envelope the electrodes 3 and 4. The electron stream interacts with the high frequency field of the cavity in the gap 8 between the electrodes 3 and 4. The electron stream is maintained in focus by the magnetic field of solenoid 30. Electrodes 3 and 4 are maintained at a high positive potential with respect to cathode 1 by means of potential source 9. The same source is employed to maintain the collector 2 at a potential lower than that of 3 and 4. The high frequency by-pass capacitors 65 and 66 are to prevent high frequency dissipation in the power supply leads to the cathode 1 and plate 2.

Operation of this arrangement as an amplifier may be as has been described in connection with Fig. 1 in the reference to grid 12. Electrode potentials are adjusted so that with no input from line 41, 42 no electrons are collected by plate 2,

all being returned toward the cathode 1. Since there is no collection of electrons the density of the electron stream remains constant and there is no generation of energy in the resonator 7 due to the stream passing through the gap 8 between electrodes 3 and 4. Now, assume a high frequency input from line 41, 42. The high frequency voltage thus impressed between the cathode 1 and grid 2 permits more or less electrons to enter the electron stream from the cathode so that the density of the stream is caused to vary in accordance with the input from line 41, 42. Since now the electron stream is not uniform in density but varied in accordance with the input, high frequency energy in accordance with the input will be generated in the resonator 7 by the electrons vibrating back and forth across the gap 8. The resonator may be tuned by adjustment of member 47 along the line 48, 49 and output energy may be taken from line 21, 22.

As previously mentioned, source 14 provides bias potential between the cathode 1 and grid 12. This bias may serve several purposes. The negatively charged grid will protect the cathode from destructive bombardment by electrons returned toward it. The bias may be adjusted to group electrons closely to a desired degree by so relating it to the high frequency input voltage that electrons enter the stream only at peaks of input voltage. Under this condition there is no electron current when there is no input and higher operating efficiency is had. By connecting output line 21, 22 to input line 41, 42 through such a length of line that a cooperative phase relation exists between the input and output voltages, self-oscillation will occur and by proper adjustment of the grid bias an efficient generator of high frequency energy is had.

When a grid such as 12 is employed to vary the electron stream by space charge control excessive loading of the input, circuit is generally experienced at high operating frequencies. To overcome such difficulty in this vibrating electron type of device, it is intended that the design and adjustment be such that the electron transit time across the gap between the cathode and control grid be critically related to the period of the frequency of operation. The desired critical relation is that the electron transit time across this gap be approximately a period between that of any whole number of cycles of the operating frequency and of that number increased by one-half cycle.

Fig. 5 shows another amplifier arrangement where the output energy is generated in a resonant cavity by the motion of electrons vibrating back and forth through the high frequency field of the cavity. Here, however, the electron stream is controlled by the high frequency input through the medium of another resonant cavity through the field of which the electron stream first passes. In Fig. 5 the output cavity resonator 7, as well as the electron gun and connected elements bearing the same designations as in previous figures, have the same functions as in those figures. Construction of the electron gun in this figure is similar to that of Fig. 2 except that additional rings 59 and 57 are sealed into the glass envelope to which are connected the input resonant cavity 50 and the composite accelerating electrodes 53, 55 and 54, 56. The composite electrodes are similar to electrodes 3, 5 and 4, 6 described in connection with Fig. 2 and, as mentioned there, each may be polarized to direct its field in either axial direction. Elec-

trodes 53, 55 and 54, 56 are associated with the input cavity 50 which is excited at high frequency by an input from the coupled coaxial line 51, 52. Since electrode portion 53 is polarized at a higher potential than portion 55 the electrons from cathode 1 are accelerated toward gap 58 between rings 59 and 57, a space free of accelerating field between electrode portions 53 and 54, which are connected together by the cavity shell 50 and so polarized at the same potential. Electrode portions 56 and 5 are polarized at the same potential and somewhat lower than the potentials applied to portions 53 and 54 and to 3 and 4. This potential, that of 56 and 5, must meet two requirements. First, it must be such that the electrons proceeding to the right from the cathode 1 may pass 56 and 5 and not be returned toward 1, and second, it must be such that electrons which are reversed by electrode 2 and are proceeding toward the left through gap 8, may not continue to the left beyond the region of 5 and 56 into the gap 58 in the input cavity but are reversed and returned to the right to pass again through gap 8. As before, the potential of electrode portion 6, which may be the same as or slightly different from the potential of 2, is made less than the potential of 3 and 4 so that the accelerating fields of both electrodes 3, 5 and 4, 6 are directed toward gap 8.

In operation electrons emitted by cathode 1 are accelerated to the right toward gaps 58 and 8 and collector 2. If there be an input so that there is high frequency current flowing in the resonator 50 there will be a high frequency field in the gap 58 so that the electrons in passing through will be accelerated or retarded depending upon the portion of the cycle during which they pass. In traversing the path between gap 57 and gap 8 the accelerated electrons will tend to overtake the retarded electrons so that a grouping of electrons takes place resulting in a charge density variation of the electron stream which is in accordance with the input from line 51, 52. In this condition it crosses gap 8 and through interaction with the field there generates, in cavity resonator 7, high frequency energy in accordance with the input from line 51, 52. This energy may be conducted to a utilization circuit through line 21, 22 or by any other suitable coupling means. The electrons having crossed gap 8 once proceed toward electrode 2 but are reversed due to the low potential of 2 and the reversed field within electrode 4, 6 and cross the gap 8 in the opposite direction again delivering energy to cavity 7. The electrons, then proceeding to the left, are again reversed by the field within electrode 3, 5 and sent to the right through the gap 8 to again deliver energy to the cavity 7. This back-and-forth motion is maintained until, after a number of useful energy transfers, the electrons are collected at electrode portions 3 and 4.

It is apparent that in this circuit arrangement the grouping of electrons which occurs as the electrons pass between gaps 58 and 8 because of the velocity variations introduced at gap 58 is not essential to operation because sorting action may be had by adjusting electrode potentials so that the electrons accelerated the most will reach electrode 2 and be eliminated after a single traversal of gap 8 and only the slower ones are returned to vibrate back and forth, delivering energy to the output cavity resonator 7 during a number of traversals of gap 8 before being collected.

It is evident also that an alternative structure, the equivalent of Fig. 5, may be one similar to that of Fig. 3. That is, after eliminating grid 12, transformer 31 and potential source 14 from Fig. 3, that figure may be expanded to be the equivalent of Fig. 5 just as Fig. 5 is in effect an expansion of Fig. 2.

To those versed in the art other circuit and structural variations within the spirit and scope of the invention will be apparent.

What is claimed is:

1. A high frequency electronic device comprising a hollow cavity resonator capable of being energized to support high frequency electrical oscillations to produce a high frequency electric field, a source of electrons external to the resonator, an electron collecting electrode spaced from the electron source, and means for causing electrons from the source to traverse at least portions of a path extending between the electron source and the collecting electrode, the traversed portions of the path including a region occupied by the high frequency electric field and including also spaces on each side of that region which are free from the high frequency field, said means comprising an accelerating electrode located along the said path and so polarized as to propel electrons through the high frequency field region in the direction away from the electron source, and a retarding and reversing electrode located along the path on the side of the high frequency field region opposite the electron source and so polarized as to propel electrons through the high frequency field region in the direction toward the electron source.

2. A high frequency device comprising a hollow cavity resonator capable of being energized to support high frequency electrical oscillations to produce a high frequency electric field, a source of electrons external to the resonator, an electron collecting electrode spaced from the electron source, the resonator being located between the electron source and the collecting electrode and having an opening in its structure such that electrons traversing the path between the electron source and the collecting electrode pass through the high frequency electric field associated with the resonator in the vicinity of the opening and through regions on each side of the high frequency field region which are free of high frequency field, an electron accelerating electrode located along the said electron path and polarized such as to propel electrons through the high frequency field in the direction away from the electron source and an electron retarding and reversing electrode located along the electron path on the side of the resonator opposite the electron source and polarized such as to propel electrons through the high frequency field in the direction toward the electron source, the electrode polarizing potentials being of such magnitudes that electrons are caused to vibrate back and forth through the high frequency field and through the field free regions on each side of the region of the high frequency field with a period of vibration approximately an odd number of times the period of the cavity resonator, whereby high frequency energy is transferred from the electrons to the high frequency field during successive traversals of the field.

3. A high frequency electronic device comprising a hollow cavity resonator capable of being energized to support high frequency electrical oscillations, a gap in the structure of the resonator such that electrons projected across the

gap will pass through the high frequency electric field associated with the resonator when it is energized, a space on each side of the gap which is free from the high frequency field, a source of electrons external to the resonator, an electron accelerating electrode so positioned and polarized with respect to the electron source as to propel electrons from the source through the high frequency electric field across the said gap in the direction away from the electron source, an electron retarding and reversing electrode positioned along the path of the above-mentioned electrons on the side of the gap opposite the electron source and so polarized as to stop, reverse and propel at least some of the electrons through the high frequency field across the said gap in the direction toward the electron source, and electric potential means for polarizing the said electrodes, the polarizing potentials being such that electrons are caused to vibrate back and forth through the high frequency field across the said gap and through portions of the field free spaces on each side of the gap delivering energy to the high frequency field during successive traversals of it and such that the period of vibration is approximately an odd number of times the period of the cavity resonator and the period for transit of the electrons across the gap is less than half the period of the cavity.

4. A high frequency electronic device according to claim 3 and including a resistor in series with the retarding and collecting electrode for the purpose of preventing parasitic oscillations.

5. A high frequency electronic device according to claim 3 and including a resistor in series with the space current path to the electron source for the purpose of preventing parasitic oscillations.

6. A high frequency electronic device comprising a resonant cavity capable of being energized to support high frequency electrical oscillations, a gap in the structure of the cavity such that electrons may be passed across the gap through the high frequency electric field associated with the cavity when it is energized, a source of electrons external to the cavity, and means comprising electron accelerating electrodes polarized to produce oppositely directed accelerating fields for causing electrons from the said source to vibrate back and forth through the high frequency field across the said gap in the cavity structure, over substantially the same path, portions of the said path at each extremity of the portion through the high frequency field being free of high frequency field.

7. A device according to claim 6 with the addition of means for producing in the region of the electron path a magnetic field of which the lines of force are parallel to the electron path.

8. A device according to claim 6 in which the accelerating electrodes are of composite structure with accelerating fields directed toward the high frequency field at the gap in the cavity.

9. A device according to claim 6 in which the accelerating electrodes are of composite structure with accelerating fields directed toward the high frequency field at the gap in the cavity and including means for maintaining a potential difference between the portion of the composite electrode adjacent to the cathode and the cathode for the purpose of focusing the electron stream.

10. A high frequency electronic device comprising a resonant cavity capable of being energized to support high frequency electrical oscillations.

lations, a gap in the cavity structure such that electrons projected across the gap pass through the high frequency electric field associated with the cavity when it is energized, a source of electrons external to the cavity, means comprising electron accelerating electrodes polarized to produce oppositely directed accelerating fields for causing electrons from the said source to vibrate back and forth across the said gap in the cavity structure and means for controlling the electron flow from the said source in accordance with a modulating signal.

11. A high frequency electronic device comprising a hollow cavity resonator capable of being energized to support high frequency electrical oscillations, a gap in the cavity structure such that electrons projected across the gap pass through the high frequency electric field associated with the resonator when it is energized, a source of electrons external to the cavity, means comprising electron accelerating electrodes polarized to produce oppositely directed accelerating fields for causing electrons from the said source to vibrate back and forth across the said gap in the cavity structure delivering energy to the high frequency field during successive traversals of the gap, and means for varying at the resonant frequency of the resonator the electron flow from the electron source.

12. A device according to claim 11 in which the means for varying the electron flow from the electron source comprises a space charge control element adjacent to the electron source, connected to a high frequency input circuit and so polarized with respect to the electron source that the electron transit time between the source and the control element is critically adjusted to a value such that the loading on the input circuit is a minimum.

13. A device according to claim 11 in which the means for varying the electron flow from the electron source comprises a space charge control element adjacent to the electron source, connected to a high frequency input circuit and so polarized with respect to the electron source that the electron transit time between the source and the control element is adjusted to be a period between that of any whole number of cycles of the field and of that number increased by one-half cycle.

14. In a high frequency amplifier, a resonant cavity input circuit, a resonant cavity output circuit, an electron emitting cathode, an electron collecting electrode spaced from the cathode, means for causing a stream of electrons to leave the cathode and traverse at least portions of the path between the cathode and the collecting electrode, the input and output resonant cavities having openings in their structures and being so placed along the electron path between the cathode and the collecting electrode that electrons

from the cathode pass first through the high frequency electric field associated with the input cavity in the vicinity of the opening in that cavity then through the high frequency electric field associated with the output cavity in the vicinity of the opening in that cavity, there being also regions along the electron path on each side of the last-mentioned opening which are free of high frequency field, the said means for causing electrons to traverse the said paths comprising at least one electron accelerating electrode so polarized as to propel electrons in the direction away from the cathode through the high frequency field and the regions free of high frequency field in the vicinity of the opening in the output cavity, and at least one accelerating electrode so polarized as to propel electrons in the direction toward the cathode through the high frequency field and high frequency field free regions in the vicinity of the opening in the output cavity, the polarizations of the accelerating electrodes being of such magnitudes as to cause electrons to vibrate back and forth through the said high frequency field and field free regions associated with the output cavity with a period of vibration approximately an odd number of times the period of the high frequency field, delivering energy to the high frequency field during successive traversals of the field, means for transferring high frequency energy from the output cavity to a utilization circuit, and means for energizing at high frequency the input cavity whereby high frequency variations are impressed upon the electron stream from the cathode as it passes through the high frequency field associated with the input cavity in the vicinity of the opening in the input cavity structure.

15. An amplifier according to claim 14 in which the means for impressing the high frequency variations upon the electron stream as it passes through the high frequency field associated with the input cavity are means for producing variations in the electron velocities.

16. An amplifier according to claim 14 in which the means for impressing the high frequency variations upon the electron stream as it passes through the high frequency field associated with the input cavity are means for producing variations in the charge density of the electron stream.

17. An amplifier according to claim 14 in which the accelerating electrode potentials are made such that the electron transit time through the high frequency field associated with the input cavity is a period between that of any whole number of cycles of the field and of that number increased by one-half cycle.

18. A device according to claim 14 in which accelerating electrodes are connected electrically to the cavity structures.

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