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3,233,140

CROSSED-FIELD DYNAMIC ELECTRON MULTIPLIER

Filed July 25, 1961

4 Sheets-Sheet 1

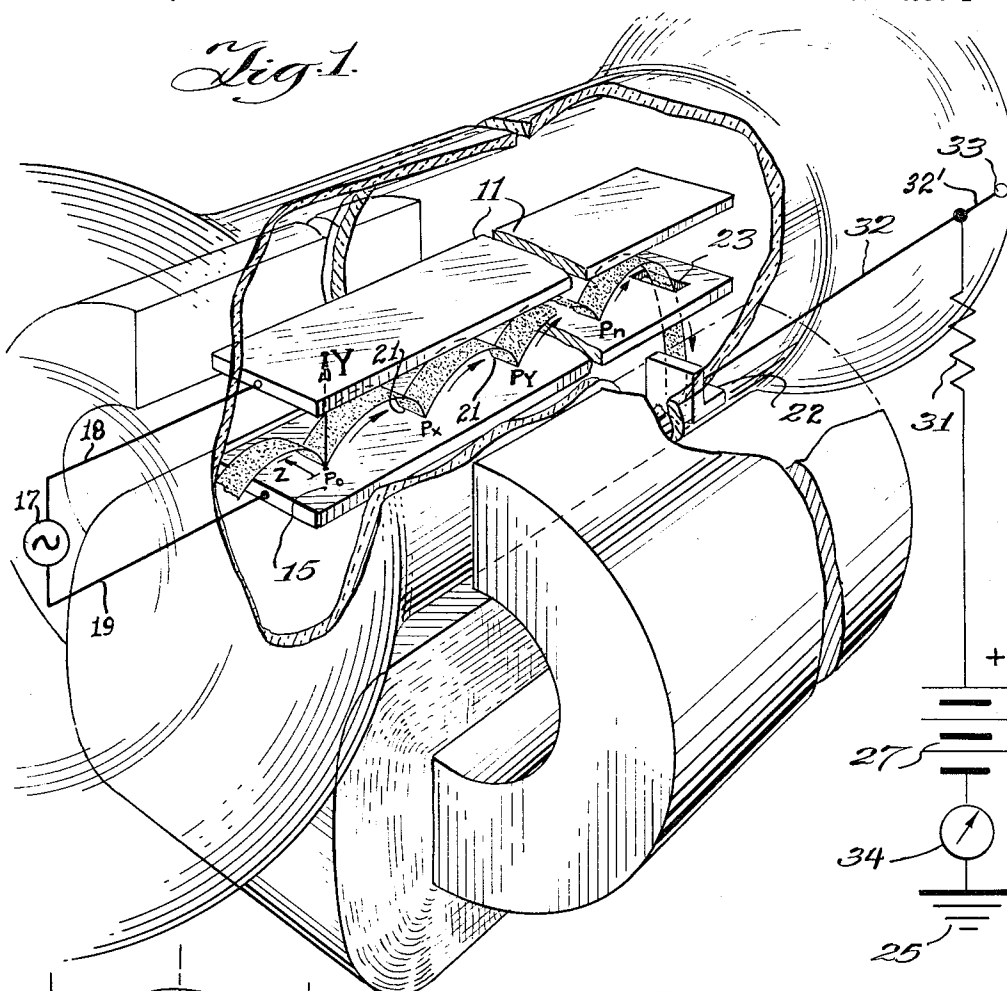
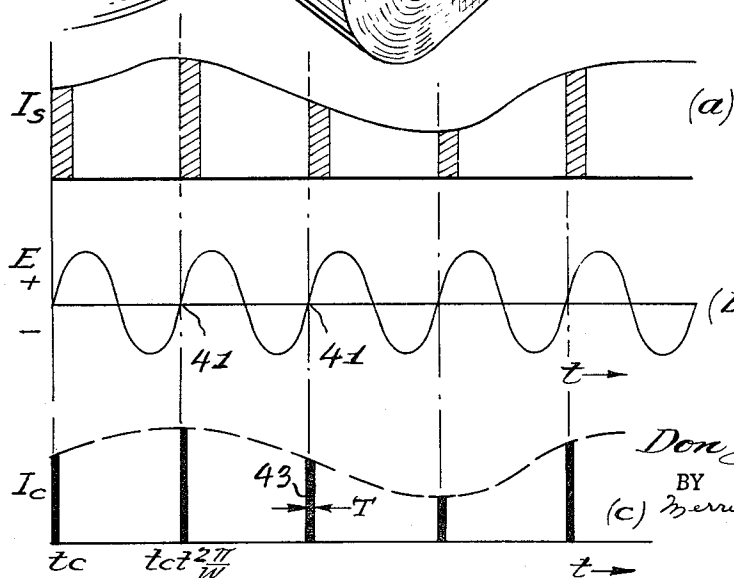


Fig. 2.

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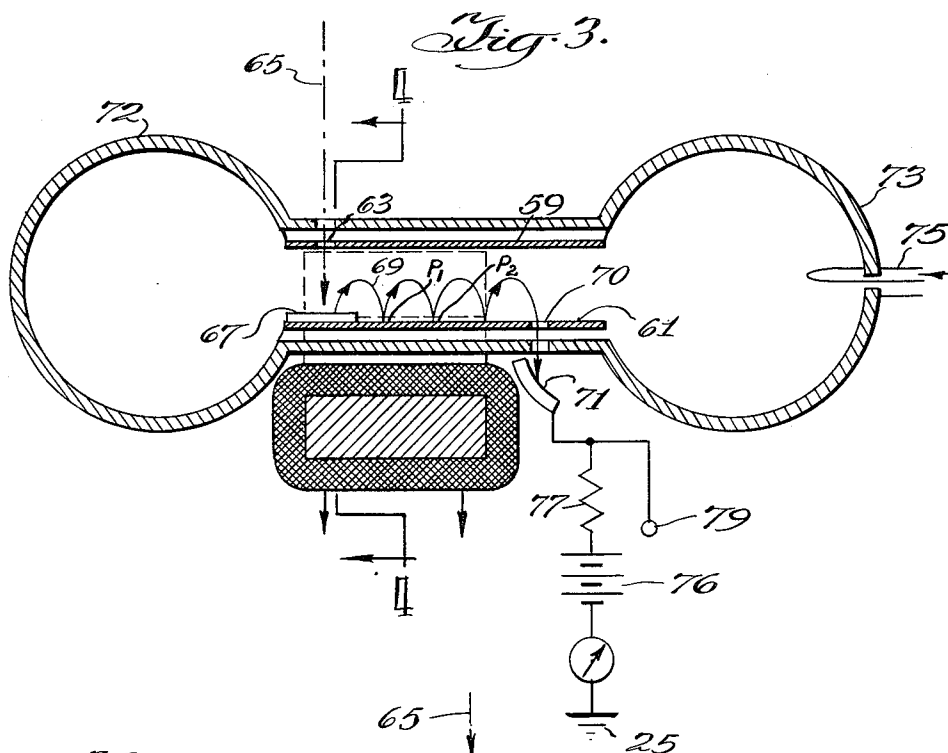
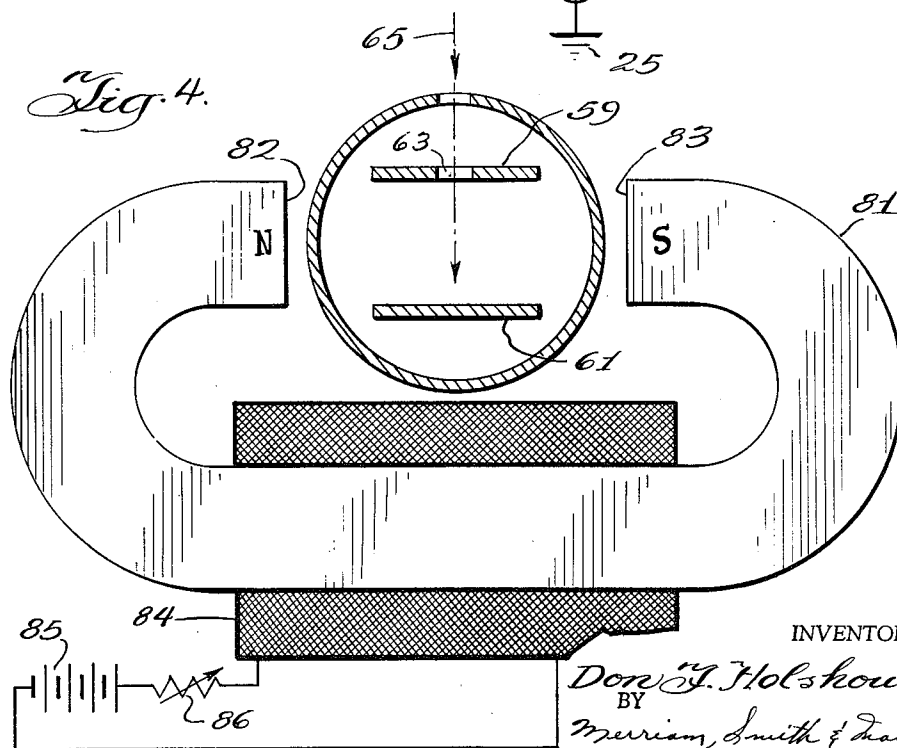
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CROSSED-FIELD DYNAMIC ELECTRON MULTIPLIER

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4 Sheets-Sheet 3

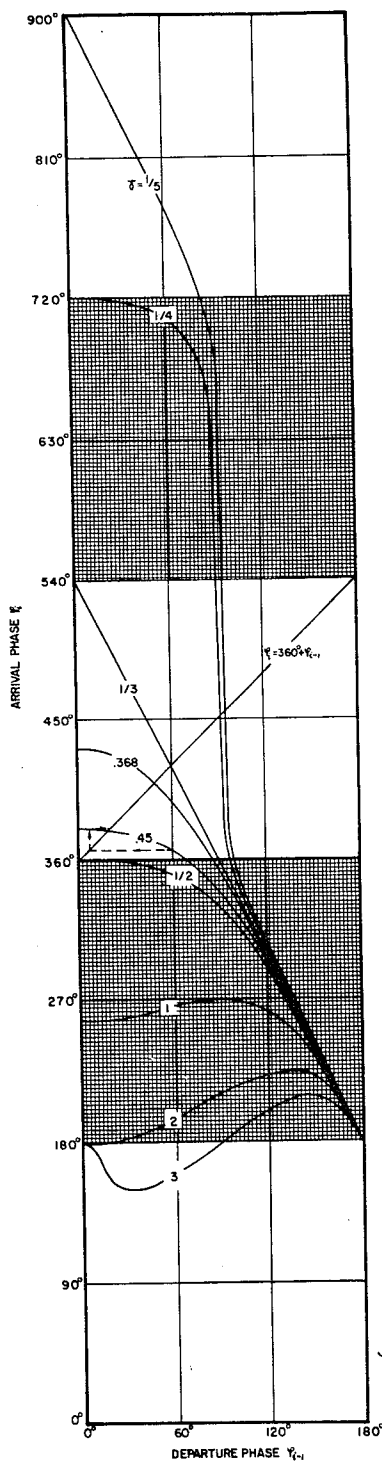


Fig. 5.

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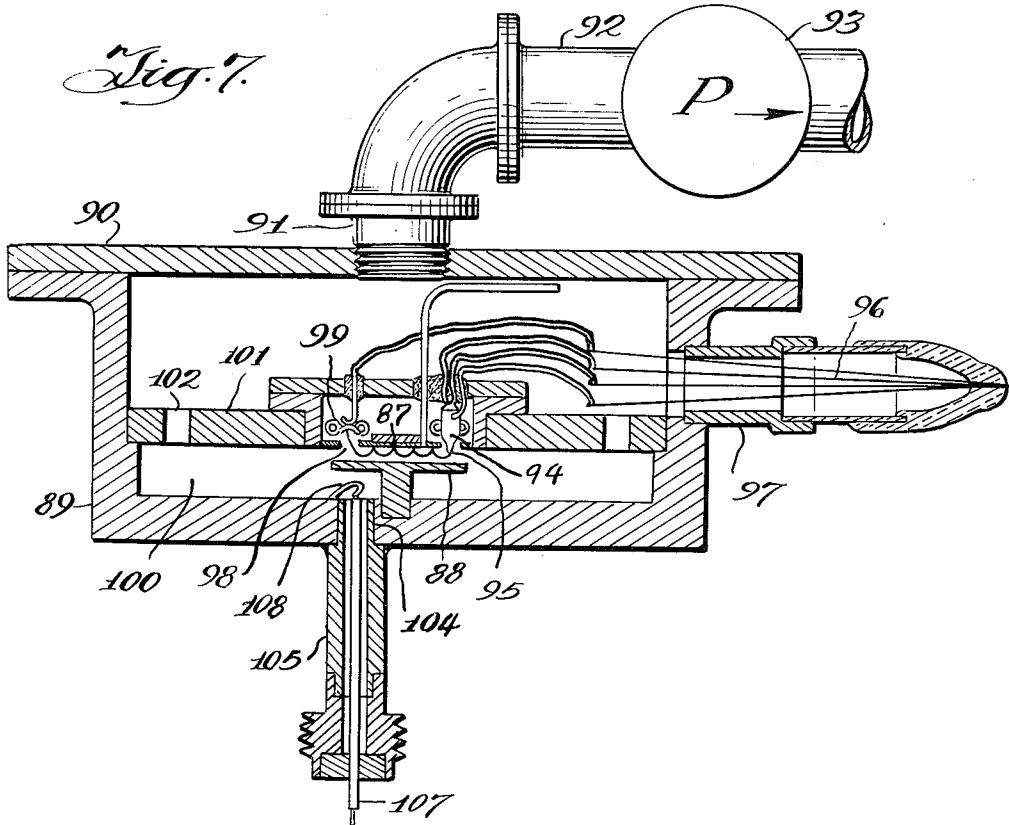
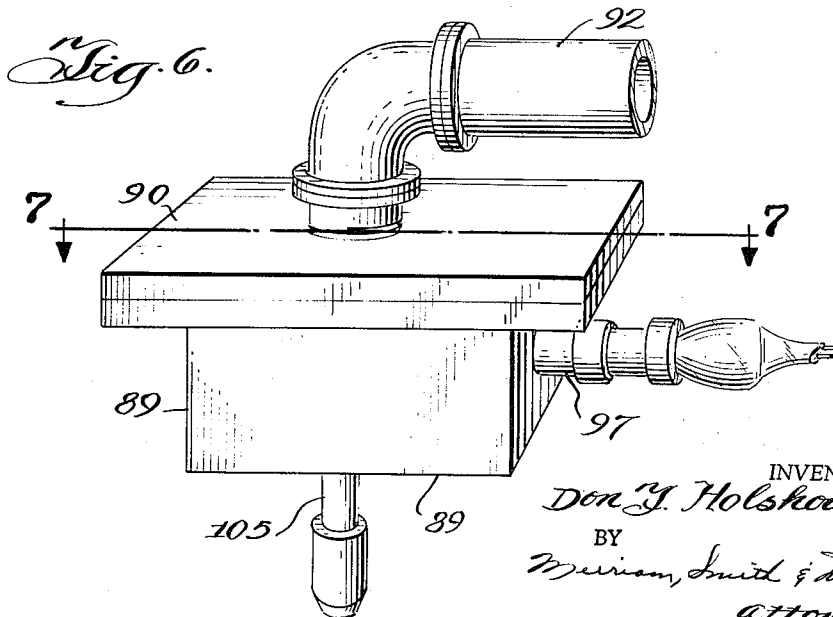
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CROSSED-FIELD DYNAMIC ELECTRON
MULTIPLIER

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Filed July 25, 1961, Ser. No. 126,672
15 Claims. (Cl. 315-12)

This invention relates to electron multiplying devices whereby the number of electrons in an electron stream may be multiplied by secondary emission for subsequent utilization in a load component.

In the past, efforts have been made to provide electron multiplication by multi-stage electrostatic multiplier devices of the character used at times in connection with the photomultipliers, television camera tubes and receiving tubes. In many respects, electron amplification of electron streams modulated at microwave frequencies has not proved particularly useful in electrostatic multiplying devices. This is due primarily to the spread in the transit time for the electrons at such frequencies.

Electronic devices for multiplication by secondary emission in what has been termed a "dynamic" type of multiplying device have also been proposed by Farnsworth and were discussed in the "Journal of the Franklin Institute," vol. 2, page 411 (1934). In the dynamic type of operation, a high frequency electric field is applied between two electrodes appropriately spaced. Electrons introduced into the field region in the proper phase relationship will strike one of the electrodes to produce secondary electrons which, in turn, then travel to the opposing electrode there to generate more electrons. The build-up in electron population proceeds in this fashion if the field is maintained or until other processes, such as a gas-discharge or space-charge, disrupt the process. However, many difficulties have been experienced and no known practical method has been discovered to limit the electron build-up to a prescribed level for the obtaining of an output electron current which is proportional to the primary or input electron current. In addition, devices of the so-called dynamic type permit only a narrow range of electric field intensities which is very difficult indeed to maintain under the influence of electron loading.

In the prior art, as disclosed, for instance, by Banks U.S. Patent No. 2,113,264, dated April 5, 1938, a structure has been proposed wherein a row of discrete electron emitting surfaces is arranged in one plane located opposite each of the emitters and positioned in parallel relationship with respect thereto is a corresponding row of field electrodes. Connections are established between the electrodes of the two sets so that when an alternating potential is applied, all even numbered electrodes of the emitting set and all odd numbered electrodes of the field set assume the same instantaneous potential. Likewise, at such moments, all odd numbered emitting electrodes and all even numbered field electrodes assume the same instantaneous potential. As electrons are passed and caused to move from one to another of the emitting electrodes, they are also subjected to the action of a magnetic field which is arranged to extend between the transverse rows of electrodes. The described structure of the prior art, however, is such that an electron moving from the initial emitting electrode to a final collector electrode must move in a finite and pre-established number of steps regardless of the amplitude of the exciting alternating potential and regardless of the strength of the magnetic field.

The present invention makes a disclosure of a method and apparatus through the use of which secondary electron multiplication occurs with a tightly controlled transit time along an electrode element adapted to emit cop-

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ously secondary electrons when impacted by a stream of arriving electrons of suitable velocity. There is a field electrode associated with the emitting electrode. This field electrode is maintained in substantially uniformly spaced relationship relative to the emitter electrode. In the operation of the device, a high frequency or microwave electric alternating potential of known amplitude is applied between the pair of uniformly spaced electrodes. A steady magnetic field is also applied in combination with and in a direction transverse to the electric field and to the electrodes in such a way that when an electron stream impacts the emissive surface secondary electrons are released. The potential effective on the field electrode, when positive relative to the emitting surface, causes the electrons released to be subjected continually to both the magnetic field and the accelerating electric field whereby they are caused to return to the emissive electrode at known regions there to emit additional secondary electrons and to repeat the effect at successive regions along the electrode. The trajectory of the electron movement is established and controlled by the strength of each of the electric and the magnetic fields. The transit time is determined substantially by the magnetic field. The electric field is mainly the means to establish the path length and energy of impact along the emissive electrode.

This type of apparatus may conveniently be designated as a dynamic crossed-field electron multiplier having provisions for establishing therein a movement of electrons so that a pre-selected number of multiplication steps is caused to occur along a single active electrode of simple geometry in accordance with the operating parameters selected.

The apparatus and method of the present invention is usable not only for electron amplification but also for heterodyne conversion, pulse generation or even linear phase expansion. The device herein to be described eliminates the transit time problem, heretofore so significant in electron multiplying devices, and it provides for the development of controlled output currents which are proportional to an applied input current (modulated or unmodulated, as the case may be). Input primary electrons are either injected into the apparatus or actually developed therein, such as by photoelectric emission, to provide a flow of electrons into the region of the two spaced electrodes to which the high frequency electric field is applied and transverse to which the steady magnetic field is concurrently applied.

The electric field applied is always of sufficient strength so that during its positive half cycle, released electrons are drawn away from the emitting surface and caused to move within the device according to a pre-selected path to be so directed that they impinge upon selected regions of the electrode member releasing the secondary electrons at a spaced region from which the electrons are then directed through the device to produce secondary emission at each point of impact. The electrons released from the secondary emitting surface, while directed outwardly therefrom toward the field electrode under the influence of the electric field, do not actually reach the second spaced field electrode but are controlled in their path by such electrode due to the exciting field applied. The magnetic field applied is strong enough so that the emitted electrons tend to curve away from the second or field electrode according to a generally clockwise pattern and progress in a direction along the electron emitting electrode. The progression of electrons impinges upon the first electrode in a succession of steps removed from the point of initial impact toward a collecting electrode. The electron stream collected at the collecting electrode finally provides the output signal which is sup-

plied to any appropriate transducer or utilization apparatus.

A condition necessary for repeated multiplication is that the secondary electrons should leave the impacted electrode either during the accelerating part of the alternating high frequency cycle or if prior thereto, that the released electrons shall have sufficient velocity to leave the surface in spite of a decelerating field and then with the sign of the field changing to an accelerating field, follow the desired trajectory after the field becomes positive.

As will be apparent from the foregoing, the invention has as one of its primary objectives that of providing an improved electron multiplying device usable for many and varied purposes, as well as providing a device of high efficiency which can be constructed with ease and at relatively low cost. Other objects will follow from what is to be described.

The invention may assume many and various structural forms and as herein illustrated and suggested and consequently it has been shown and illustrated herein in some instances in schematic form in order to explain more readily its nature and operation.

By the various drawings, FIGURE 1 is a diagrammatic view of a two-electrode electron multiplying device into which a beam of primary electrons is injected in the cross-field region so as to impinge upon one of the electrodes and to be collected following amplification in proper and determinable number of steps at an output electrode to be supplied to a suitable transducer;

FIGURE 2 is a group of curves which, by its parts (a), (b) and (c), is intended to represent the relationship of the sampling period to the exciting high frequency field and the output collector currents;

FIGURE 3 is a schematic representation of a modified form of multiplier device adapted to respond under the influence of an in-falling exciting light beam;

FIGURE 4 is a view of the multiplying device of FIGURE 3 taken along the line 4—4 thereof to show in particular the relationship of the exciting magnetic field to the applied electric field;

FIGURE 5 is a series of curves graphically to represent the relationship between the arrival phases of an electron for amplification and the departure phase of the electron;

FIGURE 6 is a view of an assembled multiplier device incorporating the principles of operation depicted by the preceding figures; and

FIGURE 7 is a sectional view of the device of FIGURE 6 taken substantially along line 7—7 of FIGURE 6.

In making reference now to the drawings for a further understanding of the invention, the apparatus depicted by certain of the figures has been shown, for convenience, with an electron stream which is of pencil formation. This is merely for convenience of illustration and it will be understood that in most operations, the electron stream will actually be in more or less of a band or ribbon-like formation, as by FIGURE 1, and the quantity of electrons included in the electron flow will be substantially greater than has been diagrammatically indicated.

Making reference now to the drawings and first to FIGURE 1 thereof, the depicted schematic device is shown as being provided with an upper or field electrode 11. This electrode is shown as being of such length that only few electron impacts occur along its length but it is actually a relatively long electrode element which functions as a field electrode and is positioned in substantially uniformly spaced relationship with respect to a like size emitting electrode 15. The cooperating emitting electrode 15 is coated with electron emitting material and is impacted by the electrons flowing within the device so that it releases secondary electrons at each impact. The coating of electrode 15 which provides the release of secondary emission may be of many and various substances. A

caesium-oxide coating on a silver electrode will provide a ratio of about 4.0 secondary electrons released per arriving primary electron arriving over the range of energy that the electrons should have upon returning to and impacting the multiplying surface of electrode 15. Various other coatings with higher or lower emission ratios, as are well known in the art, may be used as alternatives as the coating, per se.

In most installations, the plates or electrode elements 11 and 15 extend parallel to each other with a uniform spacing. In some installations, it is possible to form the electrodes 11 and 15 as cylindrical elements fitted within each other, in which case either of the electrodes may be the emitting electrode depending upon the geometry of the device. As will be apparent from what is to follow, the showing of FIGURE 1 illustratively may be considered as the development of the cylindrical electrode, if desired.

In the operation of the device, the electrode element 15 is adapted to release electrons from its surface as a result of electron impact thereon. As is known, this release occurs as secondary electron emission and where the impacting voltage is of a suitable value, illustratively something of the order of 50 volts (or in that general range), more than one secondary electron is released per arriving primary electron. This condition holds until the impacting electron strikes the surface under the influence of a field strength which exceeds that of a second so-called "cross-over" point, as a result of a rather substantial voltage difference between the electrodes which is not contemplated in the device described. For the voltage range herein to be considered, it will be assumed that the impacting electrons arrive and depart under the influence of an alternating current field such that, at times, the voltage difference between the electrodes (for instance at nodal points of the applied alternating field) is zero and other times sufficiently high to provide for secondary emission, say not to exceed several hundred volts.

In the described apparatus, a high frequency voltage is applied between the plates or electrodes 11 and 15 from any suitable source, such as that conventionally represented as 17 having its output connected by conductors 18 and 19 to the electrode elements 11 and 15, respectively. Electrons developed in any desired fashion and by any appropriate source are assumed to enter between the electrodes 11 and 15 in such a way as to follow illustratively the path indicated at 21 to impinge upon the electrode 15 at a point conventionally shown as P_0 . The electrostatic field exerted between the electrodes 11 and 15 by application of the field of high frequency source 17 is that which is schematically represented in FIGURE 1 by the vector P_0-y . The frequency of the source 17 is preferably chosen in a range of 100-300 megacycles per second to values of at least one order of magnitude higher.

Concurrently with the application of the high frequency between the electrodes 11 and 15, a magnetic field is applied by virtue of a strong permanent magnet or by virtue of an electromagnet whose field becomes effective in the direction P_0-z or in planes parallel thereto. It will be seen that this magnetic field is thus effective in a direction perpendicular to that along which the electrostatic field becomes effective and also transverse to the long dimension of the electrodes diagrammatically shown at 11 and 15.

On the diagram of FIGURE 1, the electrons entering between the electrode members 11 and 15 along the path 21 may be assumed to have been applied as an electron beam originating in any appropriate thermionic or other section of the device leading into the space between the electrodes 11 and 15 by focusing thereupon, or, alternatively, the electron flow may be assumed to have been directed into the region between the electrodes 11 and 15 by way of a heated cathode from which the electron flow

is appropriately modulated under the control of any desired input signal. As a further alternative, the electron flow shown to occur along the path 21 may be developed photo-electrically, illustratively, as will be more particularly shown by FIGURE 3, later to be discussed.

As the electron stream along the path 21 moves between electrodes 11 and 15, the electrons which strike or impinge upon the electrode 15 release secondary electrons, provided the field and the alternating potential of the high frequency applied is properly selected, as will be discussed more particularly in connection with the curve of FIGURE 5. The released electrons in the form of secondary electrons are subjected to both the high frequency field between the plates or electrodes 11 and 15 and the applied transversely acting magnetic field. This causes the electrons to follow a generally arcuate path with the released electrons tending to progress toward the electrode 11 but then curving to follow an arcuate path to return to the electrode 15 at some point such as P_x at which time a similar and subsequent release of secondary electrons occurs. The release and return of the electrons with the static and the magnetic fields applied continues and occurs at various steps schematically represented as P_x, P_y until finally it reaches the step $P_{(n-1)}$, which will be assumed to be the next to the last step for a condition where n impacts occur, after which the release of electrons brings the electrons to return to the plate or electrode 15 in the point P_n after which the next point is the collecting point schematically shown at 22. Collector point 22 is reached by the electrons falling through the slotted portion 23 of the electrode 15 to reach the collector element.

The collector 22 is maintained electrically separate from the electrodes 11 and 15 and it is held at a positive potential relative to ground 25 (or some other fixed point) by some suitable voltage source, such as 27. Source 27 supplies a positive potential through the output or load resistor 31 which connects through conductor 32 to the collector electrode 22 and through the conductor 32¹ to the output terminal 33. If desired, a metering device, schematically shown at 34, may be included in the output circuit. The output resistor 31 provides the load; output signals measured by the current flowing are then available at the terminal point 33 for connection to any suitable form of transducer or load circuit.

If reference is now made to FIGURE 2 of the drawings, and first to curve (a) thereof, it may be assumed that time is represented by the curve abscissa and that electron current is represented as the ordinate I_e . The shaded portions of the curve represent the sampling periods over which secondary electrons are collected. This period may be of a selected angle (electrical) but must be less than a 90° portion of the cycle of the applied high frequency field, which high frequency field is indicated by curve (b) in which the ordinate of the curve (represented as E) indicates the effective voltage at any instant. The sampling period may be adjusted with respect to the instantaneous conditions obtaining such as indicated by the voltage by changing the strength of the magnetic field applied along the direction parallel to the vector P_0-z (as in FIGURE 1).

The samples are always derived during the periods when the field extends in a positive direction and the output resulting at each sampling point is represented by the shaded portions of curve (c) of FIGURE 2. In connection with this condition, it may be pointed out that certain of the electrons in the stream may reach the electrode surface 15 at times other than that at which the field applied between the electrodes 11 and 15 is positive in the direction of the electrode 11. Consequently, at such times while secondary electrons are released as a result of impact of the surface of the electrode 15, the released electrons are not subjected to a field to draw them in the direction of the electrode 11 but rather tend to return toward the electrode 15. However, with this

condition obtaining, it usually happens that before the released electrons actually return to the surface of electrode 15, the direction of the field has changed (by having passed through the nodal point) such as point 41 on curve (b) of FIGURE 2, whereupon the released electrons tend to follow the arcuate curve schematically represented in FIGURE 1 and move along to the next impact point with the result that a useful sample or output current schematically represented by the shaded portions 43 on curve (c) is obtained.

If reference is now made, for the moment, to the curve of FIGURE 5, the relationship between the arrival phases of an electron (designated as φ) and the departure phase (designated as φ_{i-1}) is depicted. The curves of FIGURE 5 assume that the secondary electrons leaving the surface leave that surface at zero velocity. Actually, the electrons which leave the surface have a low initial velocity which tends to broaden the curve slightly but does not change the simplified operations or principles depicted by the curves of FIGURE 5. The curves of FIGURE 5 represent both the result of tests and theoretical considerations of the operational principles.

In the curves of FIGURE 5, various conditions are shown for convergence of the electrons. It is a well known fact that in an electronic device, the cyclotron frequency which is indicative of the frequency at which an electron traverses an orbit in a steady uniform magnetic field and a zero electric field is represented by the product of the electronic charge and the magnetic field density divided by 2π times the electron mass, and that a value which is representative of the convergence identified on the curves as γ is represented by the fraction of the cyclotron frequency divided by the driving frequency.

Illustratively, a curve having a slope of unity will be one where the electrons arrive and depart at the same time. Following the curves of FIGURE 5, two conditions are depicted, one in which the range in which electrons initially depart at different phases gives rise to the convergence of the electrons toward a common phase and the other wherein the range is such that the initial phase spread of electrons increases on successive jumps and the electrons will not converge.

If, for instance, a convergence factor of $\frac{1}{3}$ is to be considered, it will be noted that the curve represented as $\frac{1}{3}$ is absolutely linear and, consequently, for a departure phase of say 60°, it will be seen that the point for 60° projected outwardly toward curve $\frac{1}{3}$ reaches the curve at an ordinate value of 420° or 60° beyond a 360° position so that the arrival and departure phase is precisely the same.

On the other hand, if a curve wherein the ratio is assumed to $\frac{1}{2}$ is considered, it will be noted, illustratively for a 60° departure phase, the electron would have arrived at a phase of approximately 345° and would, therefore, have arrived during a negative portion of the exciting field and would not be able to leave. If, however, a curve shown by the ratio of 0.45 is to be considered and it be assumed that the departing electron was 60° out of phase, it will be seen that at the ordinate value at which the 60° line intersects the curve the secondary electron which leaves at a departure phase of 6° arrives at 360° plus 20°, etc. The dotted line of the curve indicates a graphical procedure for determining the phases of electrons on successive jumps as, for instance, between points P_0, P_1, P_x, P_y , etc. In the example considered for FIGURE 5, it can be seen that the electrons converge rapidly to a phase φ minus 360° which is equal to a departure phase of 19°. Following the curve, it will be seen that for electrons which trace their ancestry to an initial departing phase which is between 0 and approximately 68°, there will be rapid convergence but for electrons arriving at other phases this will not be true.

Following the same principle described above, it can be shown that the curve designated as 0.368 is the limiting case for convergence. If reference is now made again

to the divergence curve shown as the ratio $\frac{1}{3}$ and following the same graphical procedure through successive electron jumps, it will become apparent that two electrons initially departing at different phases give rise to electrons having a greater and greater phase difference. Since it will be apparent from what is shown on the curve that the departure-arrival phase relationship is linear with the slope minus 2, the phase difference increases after n steps by a factor 2^n . Consequently, the multiplying device described may be used as a linear phase or time expander.

From what has been stated above, it has been shown that where the ratio is of the order of $\frac{1}{3}$, divergence will occur, while where the ratio is 0.45 convergence will occur. The limiting case which represents minimum value of the magnetic field for which electron phase will focus is that for which the curve has a slope of negative unity at the point of intersection with the phase relationship 360° plus φ_{1-1} line which condition is made by the curve 0.368. It might be mentioned, as can be seen from the curve of FIGURE 5, magnetic field values which produce arrival phases in the range between 4π and 5π also lead to successive multiplications, but for this condition it is necessary to restrict the ratio to the range of 0.215 to 0.250. Following the same principles, even longer transit times are possible.

Considering the modification of FIGURE 3, the depicted device is shown as adapted to be light-excited. The device is represented schematically as comprising a pair of flat plate or electrode elements in the form of the field electrode 59 and the emitter electrode 61 of shapes generally corresponding to the electrodes 11 and 15, respectively, of FIGURE 1. Toward one end of the electrode 59, there is a window or transparent region schematically shown at 63 to permit light from an external source and modulated as desired to enter. The entering light beam is schematically represented at 65 and it is directed within the device to impinge upon a photoelectrically responsive section 67 of the electrode 61. The remaining portion of the electrode 61 is coated on the face thereof toward the electrode 59 with a suitable coating, such as platinum, to provide relatively high secondary electron emission when it is impacted by an electron stream schematically illustrated at 69 and impacting the surface of electrode 61 at various points such as P_1 , P_2 , etc., after the fashion explained in connection with FIGURE 1.

The departing electron flow, after an appropriately determined number of impacts of the electron stream 69 on the surface of electrode 61, is arranged to leave the region of the electrode 61 through an exit slot or aperture 70 to impinge upon a collecting electrode 71 similar to the electrode 22 of FIGURE 1. The ends of the electrodes 59 and 61 are connected to flat band or ring sections 72 and 73 to which the exciting high frequency power is applied by the schematically represented loop as indicated. The combination is so arranged that the electrode members 59 and 61 act generally as a capacity and the loop sections 72 and 73 act as inductive elements so that the combination of the inductive loop sections 72 and 73 and the capacity between the electrodes 59 and 61 acts as a tuned circuit which is resonant at the high frequency supplied by the coupling loop 75.

Consequently, following the principles described in connection with the material of FIGURE 1, light falling into the device along the path 65 releases photoelectrons along the path 69. The released electrons after impacting electrode 61 are suitably amplified to provide the output electron stream which passes through the opening 70 to reach the collector electrode 71. The collector electrode 71 is supplied with positive voltage from a source 76 through the output resistor 77 so that there is available at the output terminal 79 an output signal representing in amplified form the light modulation available at the input. As indicated in FIGURE 3 by dotted outline, a

magnetic field is applied to be effective as indicated particularly by FIGURE 4 in a direction transverse to the movement of the electrons in the electron stream 69 from the photo-emitter 67 to the outlet region 70 and in this respect effective in a direction similar to that shown by the vector P_0-z of FIGURE 1 so that the control over the electron impacts in FIGURE 3 is generally analogous to that already explained.

In FIGURE 4, there has been shown more particularly by the cross-sectional view, the manner of applying the magnetic field between the electrode elements where it will be seen that the core 81, which may be of generally horse-shoe or C-shaped configuration, is arranged so that the pole pieces 82 and 83 are positioned closely adjacent to the edges of the electrodes 59 and 61. Wrapped about the iron core 81 there is a suitable winding 84 to which a steady input current is applied from a schematically represented source 85, shown in the form of a suitable battery to supply current to the winding 84 through the variable resistor 86 thereby to control the intensity of the magnetic field effective. In the operation of the device, all components except magnet 81 and its winding are enclosed within a housing (not shown) which is evacuated. The device may be either a sealed-off device or it may be a device to which a vacuum pump is continually applied to maintain the vacuum. In either event, the operation is similar.

Referring now to FIGURE 6, a generally schematic but perspective view of a working embodiment of the described type of device is depicted. Considering the showing of FIGURE 6, particularly in conjunction with FIGURE 7 which represents a section on the line 7-7 of FIGURE 6, the electron emitting electrode corresponding to the electrode 15 of FIGURE 1 is shown at 87 with the second electrode corresponding to the field electrode 11 of FIGURE 1 represented at 88. The device of FIGURES 6 and 7 represents an evacuated form of housing wherein the functioning electrodes 87 and 88 are contained in and supported within an outer shell 89 having a top closing member 90. A connection is made into the envelope by way of the top opening 91 which leads through the tube 92 to an appropriate form of vacuum pump, schematically shown at 93. The pump 93 serves to maintain the complete space within the cover plate 90 and the shell 89 highly evacuated. Where desired, a sealed-off tube may be utilized but the device described and pictured is one which serves particularly in adapting itself to a wide variety of uses.

In the form of device shown in FIGURES 6 and 7, the electrons which are directed into the space between the electrodes 87 and 88 originate from an emitting cathode and anode control assembly schematically shown at 94 and are modulated by any suitable form of a modulating electrode (not shown) and ejected through the orifice 95 (held at anode potential or higher) into the region between the electrodes 87 and 88. Suitable leads indicated as a group at 96 supply both the heater current to the emitter, the modulating voltages and the voltage to the anode or accelerating electrode serving to draw the electrons from the emitting cathode. The leads are drawn out through a suitable seal schematically represented at 97 tightly secured into the wall of the shell 89. Collection of the electrons after multiplication is provided when the electrons fall through the aperture schematically represented at 98 to impinge upon the collector 99, which is held at suitable positive potential relative to the emitter in a fashion already explained.

There is also secured into the cavity 100, provided between the shell 89 and the support plate 101 having a pumping hole 102 therein, a second connection tightly secured through the cavity opening 104 which is in the form of a coaxial line having a copper coaxial outer conductor 105 and a so-called "Kovar" center conductor 107 which connect within the cavity 100 to form a coupling loop 108. The electrode 87 is held by plate 101 while

electrode 88 is held by the shell 89. Suitable seals are provided by way of any well known practice tightly to seal the coaxial conductor and the coupling loop into the outer shell 89.

As was explained particularly in the showing of FIGURE 3, the combination of the outer shell 89 and the supporting plate 101 for the various parts of the assembly form an inductive element, and the plates 87 and 88 form capacitive elements so that there may be applied through the coaxial conductor a suitable high frequency at which the combination of the formed capacity and the inductance of the elements 89 and 101 forms a tuned circuit resonating at the supplied input frequency.

Consequently, so arranged, the electrons injected through the orifice 95 into the space between the electrodes 87 and 88 follow paths generally similar to the paths discussed in connection with FIGURES 1 and 3 and are collected at the collecting electrode 99. There is applied in a direction transverse to the electrostatic field a suitable field developed by an electromagnet such as that schematically indicated at 115 which preferably has a horse-shoe core and whose pole pieces are arranged transverse to the long dimension of the electrodes 87 and 88 so that the produced magnetic field is in the direction as explained in the preceding discussion. Since high frequencies are involved in the operation, it is readily possible to incorporate the multiplying section of the device into the capacity loaded resonant cavity as indicated with the supplied high frequency provided by way of the coaxial conductor.

While not shown in connection with the diagrams of FIGURES 6 and 7 it, of course, will be apparent that the originating electron stream may be developed photoelectrically as disclosed in connection with FIGURE 3 by providing an entering window for a light beam directed into the housing. Likewise, it will be apparent that the operation may be maintained where the infalling electrons originating as an electron stream are suitably directed and controlled in a path in the fashion of a microwave amplifier. Various other forms of arrangements are possible and follow fully within the spirit and scope of what is herein described and claimed.

It will be apparent that, if desired, the field electrode may be positioned externally of the evacuated chamber or cavity since the accelerating electric field developed thereby can extend into and become effective with the emitting electrode.

In the foregoing showing and particularly in connection with that of FIGURE 3, it will be appreciated that the arrangement has not been disclosed in such a fashion that the collector electrode has been shown contained within the evacuated envelope and has not been shown so that the complete component is housed in the evacuated chamber. However, this type of showing is merely for convenience of illustration and in use the complete device is housed within an evacuated chamber or envelope as depicted particularly by the showings of FIGURES 1, 6 and 7.

Having now described the invention, what is claimed is:

1. An electronic device comprising a pair of electrodes positioned substantially parallel to each other, one electrode of the pair being adapted to release secondary electrons in a ratio exceeding unity upon electron impact, means to supply an alternating high frequency field of selected amplitude between the electrodes for producing an electrical field which is substantially uniform along the electrodes in the direction of electron travel, means to supply a magnetic field effective in a direction perpendicular to the alternating high frequency field and the electron emitting electrode, means to supply a flow of primary electrons between the electrodes, and means to collect an output electron stream following the release of secondary electrons from the active electrode.

2. The device claimed in claim 1 comprising, in addition,

tion, means to modulate the supplied primary electrons.

3. The electron device claimed in claim 1 wherein the electrodes are of strip formation and wherein the magnetic field is applied in a direction perpendicular to each of the electric field and the long dimension of the electrodes.

4. The electronic device claimed in claim 1 wherein the electrode members are of strip formation and wherein the electrode releasing secondary electrons and impacted by infalling electrons is contained within an evacuated envelope and wherein the second electrode of the pair is positioned substantially uniformly separated from the other and is supported externally of the evacuated envelope.

5. The device claimed in claim 1 wherein the applied primary electrons are photoelectrically generated.

6. An electronic device comprising a pair of substantially uniformly and equally spaced electrodes of which one is adapted to release secondary electrons in a ratio exceeding unity upon electron impact, means to supply an alternating high frequency field of selected amplitude between the spaced electrodes for producing an electrical field which is substantially uniform along the electrodes in the direction of the electron travel, means to supply a substantially constant intensity magnetic field effective in a direction perpendicular to the electrodes and the alternating high frequency field applied therebetween, means to produce a stream of primary electrons between the electrodes, means provided by the high frequency electric field and the magnetic field to cause the electron stream to impact the emitting electrode a plurality of times between its entrance and exit, and means to collect the output electron stream following the release of secondary electrons from the active electrode.

7. The electron device claimed in claim 6 wherein the spaced electrodes are of strip formation and wherein the magnetic field is applied in a direction perpendicular to each of the electric field and the electron path along the electrodes, and means to modulate the electron flow.

8. The device claimed in claim 7 wherein at least one of the electrodes and the collecting means are contained within an evacuating envelope.

9. The electronic device claimed in claim 6 wherein the electrode members are of strip formation and wherein the electrode releasing secondary electrons and impacted by infalling electrons is contained within an evacuated envelope and wherein the second electrode of the pair positioned substantially parallelly with respect to each other is supported externally of the evacuated envelope.

10. The device claimed in claim 6 comprising, in addition, a coaxial conductor having one conductor thereof connected to the pair of electrodes and means to supply the exciting voltages through the said coaxial line.

11. The method of current amplification in a device having an electrode capable of emitting secondary electrons in a quantity greater than unity per arriving primary electron which comprises the steps of developing a substantially uniform alternating electrical field of relatively high frequency along substantially the entire length of and in a direction normal to the electron emitting electrode, developing a magnetic field in a direction at right angles to the electrical field, releasing primary electrons in a region of the electron emitting electrode, subjecting the released electrons to the effect of each of the electrical and magnetic fields concurrently, moving the electrons along the emitting electrode to impact it at selected points determined by the intensity of each of the electric and magnetic fields, and collecting the electrons following a selected number of impacts on the emitting electrode.

12. The method of current amplification in a device having an electrode capable of emitting secondary electrons in a quantity greater than unity per arriving primary electron which comprises the steps of developing

a substantially uniform alternating electrical field of high frequency along substantially the entire length of and in a direction normal to the electron emitting electrode, developing a magnetic field in a direction at right angles to the electrical field, releasing primary electrons in a region of the electron emitting electrode, modulating the inflowing stream of electrons, subjecting the modulated released electrons to the effect of each of the electrical and magnetic fields concurrently, moving the electrons along the electrode to impact it to release secondary electrons at selected points determined by the intensity of each of the electric and magnetic fields, and collecting the electrons following a selected number of impacts on the emitting electrode.

13. The method of current amplification in a device having an electrode element capable of emitting secondary electrons in a quantity greater than unity per arriving primary electron which comprises the steps of producing an electron flow in the region of the electron emitting electrode, developing an alternating electric field of relatively high frequency in a direction normal to the electron emitting electrode, the said electric field being substantially uniform along the complete emitting electrode and alternately carrying the said electrode positive and negative relative to the initial electron emitting electrode, developing a magnetic field in a direction at right angles to the electric field, subjecting the released electrons to the simultaneous effect of each of the electrical and magnetic fields, progressively moving the electrons released along the emitting electrode to impact it at selected points determined by the intensity of each of the electric and magnetic fields, time controlling the electrons released in their progressive movement along the emitting electrode there to release secondary electrons to vary the compression and expansion of the impacted regions to produce phase convergence with compression and phase expansion with separation, and collecting the electrons following a selected number of impacts on the emitting electrode.

14. The method of current amplification in a device having an electrode element capable of emitting secondary electrons in a quantity greater than unity per arriving primary electron which comprises the steps of developing an electron flow in the region of the secondary emitting electrode, producing an alternating electric field of relatively high frequency in a direction normal to the

secondary electron emitting electrode, the said field being substantially uniform along the entire electrode length from the region of the initial electron flow for alternately carrying the emitting electrode positive and negative relative to the source of primary electrons, concurrently developing a magnetic field in a direction normal to the electric field, directing the primary electrons into the region of the electric and magnetic fields and the secondary emitting electrode, progressively moving the electrons released along the emitting electrode to impact it at selected points determined by the intensity of each of the electric and magnetic fields, time controlling the electrons released in their progressive movement along the emitting electrode there to release secondary electrons to vary the compression and expansion of the impacted regions to produce phase convergence with compression and expansion with impact separations, and collecting the electrons following a controllable number of impacts on the emitting electrode.

15. An electronic device comprising a pair of elongated electrodes positioned substantially in parallel relationship to each other, one of the electrodes being active and adapted to release secondary electrons in a ratio exceeding unity upon electron impact, connections for supplying an alternate high frequency field of selected amplitude between the electrodes, means to supply a magnetic field effective in a direction perpendicular to the alternating high frequency field and to the electron emitting electrode, the intensity of the magnetic field being such that electrons leaving the active surface are returned to the same surface, means to introduce a flow of primary electrons between the parallel electrodes, and means to collect an output electron stream following the release of secondary electrons from the active electrode.

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