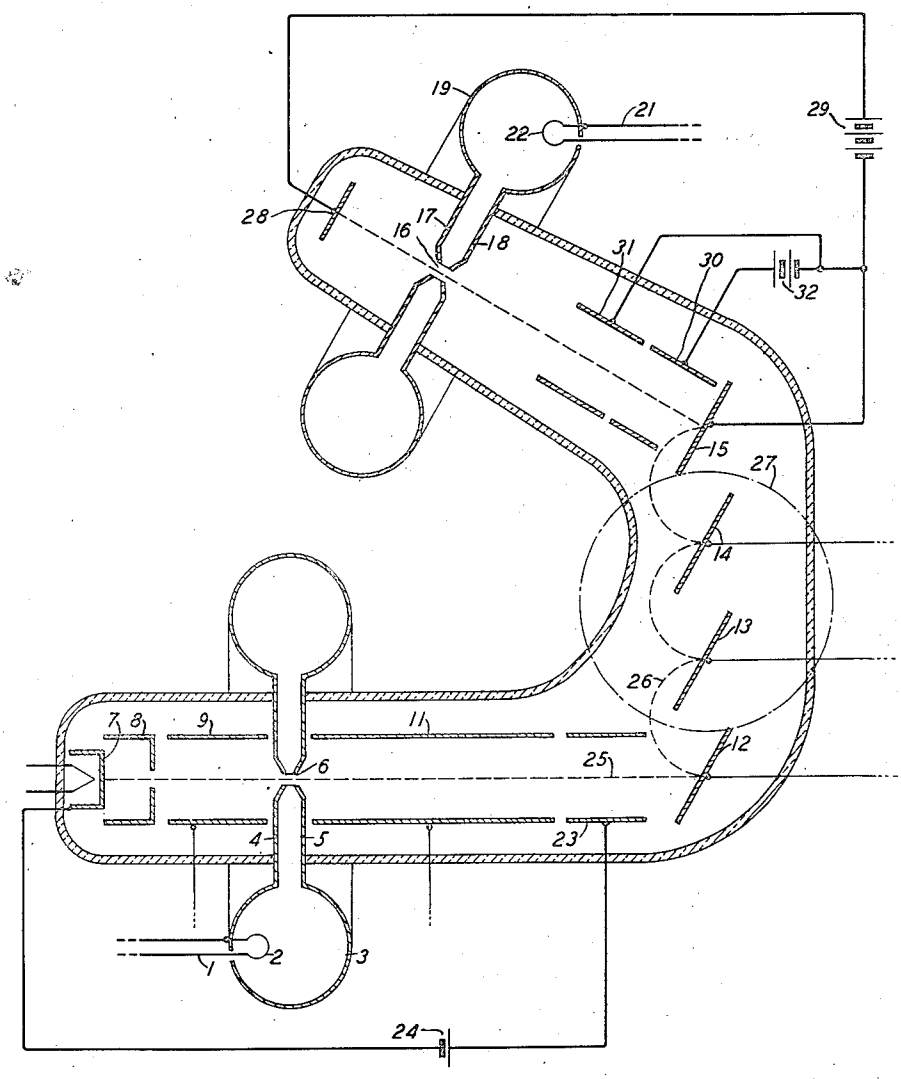
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HIGH FREQUENCY AMPLIFYING APPARATUS

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HIGH FREQUENCY AMPLIFYING APPARATUS

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7 Claims. (Cl. 250—175)

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This invention relates to electronic apparatus and more particularly to amplifying devices.

An object of the invention is to increase the gain obtainable in amplifiers utilizing density-varied electron beams.

Another object of the invention is to increase the effective input impedance of velocity-varied electronic devices.

An additional object of the invention is to increase the efficiency of the energy transfer circuits associated with the input and output of electron multipliers.

Another additional object of the invention is to provide an effective combination in a single apparatus of an electron velocity-varied amplifier and electron multiplier.

In accordance with the invention, an electronic device comprises an electron gun associated with an electron velocity variation device. The electron beam is of small magnitude in order that the input circuit connected to the velocity variation device may have high impedance. After the velocity variation the electrons of the beam are caused to traverse a drift space to become density varied. The high velocity electrons of the density-varied beam are then retarded so that their velocities will be suitable for actuation of an electron multiplier. In response to the impacts of the groups of electrons of the density-varied beam, the electron multiplier at its output electrode yields similarly spaced groups of secondary electrons which are thereafter accelerated to high velocity and focussed upon an energy-extracting gap associated with a resonant output chamber or other energy transfer circuit.

Additional features and aspects of the invention will be apparent from a consideration of the following detailed description and of the appended claims taken in connection with the accompanying drawing which illustrates diagrammatically an electron amplifying system comprising one embodiment of the invention.

In the drawing an input circuit 1 terminates in a coil 2 which is placed within the chamber or tank 3 resonant to the frequency of incoming oscillations. Forming a part of the resonant system 3 is a pair of plates 4 and 5 having an aperture or gap 6. An electron gun having a cathode 7, an anode 8 and a focussing member 9 of any well-known type serves to impel a high velocity electron beam substantially aligned with the central axis of the gap 6. The velocity of the electrons of the beam is so predetermined with respect to the effective distance of transit through the electromagnetic field of the resconant system 3 in the gap 6 that the velocities of the electrons of the beam are varied in accordance with the input waves supplied to the resonant system 3 or input circuit 1. In order to enable the impedance of the input circuit 1 to be made of large magnitude the electron beam is of small intensity. The amount of the velocity variation effected at the gap 6 is dependent upon the magnitude of the power applied from the input circuit 1 to the resonant system 3 and the resulting electromagnetic wave field intensity at the gap 6. After velocity variation of the electrons has taken place the electron beam is caused to traverse the space within a drift chamber 11 of well-known type which permits the fast electrons to overtake preceding slow electrons thus causing the velocity-varied beam to become density varied. The use of a small beam of electrons, in addition to increasing the impedance of the input circuit, improves the performance of the drift space 11 by reducing the degrouping action of space charge. This permits the use of a longer drift space, with a corresponding reduction in the velocity variation, and input voltage required at gap 6 to produce a given percentage variation in density.

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In order to increase the power available for the output circuit, the density-varied beam issuing from the output end of the drift chamber 11 is caused to impinge upon the first secondary electron emitter 12 of a multiple stage electron multiplier, the other cathodes of which are designated 13, 14 and 15 respectively. After multiplication of the amplitude of the density-varied beam by the electron multiplier the beam is accelerated to high velocity and at the same time focussed upon the energy extraction gap 16 constituted by apertures through the plates 17 and 18 of the resonant output chamber 19 which may be similar in its construction and tuning to the resonant input chamber 3. An output or load circuit 21 is coupled to the field of the resonant chamber 19 in any desired manner as, for example, by the loop 22 within the chamber.

An important aspect of the apparatus has to do with electron velocities. The velocity of the primary beam emitted by the electron gun is preferably such that during the transit of an electron from the equipotential surface corresponding to plate 4 to the equipotential surface corresponding to plate 5 the field is approximately constant. This will be true if the transit time between these surfaces is something less than ¼ cycle of the oscillations of the resonant chamber 3. This requirement is imposed by the necessity of effective velocity variation of the electrons

in the gap 6. During transit through the drift space 11 the electron velocities remain substantially the same as at the exit of the electrons from the gap 6. This velocity is considerably too high for efficient operation of an electron multiplier. It is therefor desirable that it be reduced to a magnitude at which the response of the cathode 12 is most efficient. It is also desirable that the mean velocity of the impinging electrons upon the cathode 12 be such that the variations in velocity due to velocity variation will have relatively little effect on the number of electrons emitted in response to the impact of a primary electron. This mean velocity will therefore be made such that the slope of the characteristic of the emitter relating secondary electron emission to velocity of the impinging electron is low at the mean velocity point. The desired impact velocity is attained by a retarding field produced by the tubular element 23 which is connected to the cathode 7 of the electron gun through an external path including a source 24 to render the electrode 23 slightly positive with respect to cathode 7. It will be apparent that the groups of electrons of the density-varied beam issuing from the output end of the drift chamber 11 will experience a retardation in the field of element 23 such that the electrons of the group will impinge on the surface of cathode 12 with the proper velocity. In response to impact of the groups of electrons incident upon the cathode 12 along the path indicated by broken line 25, there is emitted from cathode 12 a larger group of secondary electrons which proceed toward the second electron multiplier surface 13 along the curved path indicated by broken line 26 because of the deflecting effect of the transverse magnetic field set up by the electromagnetic coil or permanent magnet indicated by the broken line circle 27. The semicircular trajectory 26 in cooperation with the parallel position of the cathodes 12 and 13 gives rise to the very important advantage that the transit time of the secondary electrons from cathode 12 to cathode 13 is very nearly independent of the point of collision. Accordingly, the group of secondary electrons emitted at the surface of cathode 12 in response to impact of a group of primary electrons will remain in the same relative time position as it impinges upon cathode 13 since the action of the successive stages of the electron multiplier is similar to that of the first state differing primarily only in that the number of electrons in the groups is increased from stage to stage. The output of the final cathode 15 of the electron multiplier will likewise be density varied in the same manner.

It will be apparent therefore that the initial weak energy of the input circuit 1 has been made to control a relatively large electron stream by the process of velocity variation and electron multiplication which has been described. However, the density-varied beam emanating from the final cathode 15 of the electron multiplier will be of such low velocity that its transit time across a feasible energy extracting gap will be too great for efficient operation. In order to overcome this difficulty an accelerating electrode 30 is provided and is connected by an external circuit to the cathode 15 including a high potential source 32. A focussing system 31, which may consist of pairs of parallel plates or of ring elements and sources of potential, is associated with the cathode 15 and serves to focus the final beam upon the gap 16. This focussing system may be designed in accordance with the method described by J. R. Pierce, U. S. Patent 2,268,197, issued December 30, 1941. The electromotive force of the source 32 is preferably such that electrons arriving at the gap 16 will traverse it in less than ¼ cycle of the oscillations, thereby providing efficient transfer of energy to the resonant system 19. Since the electrons arrive at gap 16 in groups or clusters of electrons the peak intensities of which vary in magnitude in accordance with the weak signal currents of input circuit 1, there will be delivered to the resonant system 19 and transferred to the output circuit 21 an electromagnetic wave energy corresponding in frequency and intensity to the input energy of circuit 1 but highly amplified. This, moreover, is effected in relatively efficient manner since for the most part the couplings are directly effected between electron streams and electromagnetic fields.

The electron beam may be emitted from a circular electron gun in the form of a line or pencil. In this case the drift chamber 11 may be cylindrical with a substantially circular cross-section and the resonance systems 3 and 19 may be circular toroids centering on the axis of their respective electron beams. However, a greater effective current carrying capacity may be obtained at the expense of a somewhat smaller input impedance, if the electron gun be so designed as to emit electrons along a line instead of at a central point. In that case the cathode of the gun may be an oval or even rectangular cross-section with its long dimension perpendicular to the plane of the paper. The broken line 25 will then indicate a sheath of electron rays passing from the cathode of the gun to the cathode 12 of the electron multiplier. The resonance chamber 3 will become an elongated toroid with its longer dimension perpendicular to the paper to provide an aperture or gap 6 in the form of a slit extending in a direction perpendicular to the plane of the paper and of a length sufficient to accommodate the sheath of electron rays. In like manner, the cathodes 12 to 15, inclusive, of the electron multiplier will have their dimensions in the direction perpendicular to the plane of the paper increased to accommodate the flat electron beam. The accelerating and focussing members 30 and 31 and the resonance chamber 19 as well as the collecting anode 28 will be designed accordingly. The electron chamber 19 will have substantially the same resonance frequency as the resonant system 3 but the dimensions of its gap 16, that is, separation of plates 17 and 18 and the size of the openings in plates 17 and 18 at the gap will be determined respectively by the velocity of the electrons in that region and the magnitude of the stream which traverses the gap.

What is claimed is:

1. An electron discharge device comprising means for producing an electron beam, means positioned along the path of the beam for velocity varying the electrons of the beam, a secondary emission surface intercepting the path of the beam and adapted to emit secondary electrons in response to incident primary electrons, means also positioned along the path of the beam for setting up an opposing field in the path of the beam to slow down the electrons of the velocity varied beam and to direct the retarded beam against the secondary emission surface, whereby a beam of secondary electrons is produced having density variations corresponding to those of the incident primary beam, and output means within the discharge device and positioned along the

path of the secondary beam and electrically coupled thereto to abstract from the secondary beam energy corresponding to the density variations therein.

2. An electron discharge device comprising a multistage electron multiplier, means electrically connected to the final stage thereof for accelerating the velocities of the output electrons of the final stage of the multiplier to a high velocity, and means adjacent the path of the accelerated electrons and electrically coupled to the electron stream to extract energy from it comprising a resonant chamber having an opening aligned with the path of the accelerated electron stream whereby that stream enters the chamber and traverses a portion of the electromagnetic field therewithin to react with that field.

3. An electron discharge device comprising means for producing an electron beam, means positioned adjacent the path of the beam for varying the velocities of the electrons thereof, a drift space enclosure comprising a body of electrical conducting material having an opening extending therethrough and in alignment with the course of the electrons to permit the beam to pass through the opening within the drift space enclosure and to become density varied, a secondary electron emitting surface positioned in the path of the beam and upon which the density-varied beam impinges to cause emission of a beam of secondary electrons and output means within the device electrically coupled to the beam of secondary electrons to extract output energy therefrom.

4. An electron discharge device comprising a primary source of electrons, a secondary emitter positioned in the path of the primary electrons to emit a beam of secondary electrons in response to impact of electrons from the primary source, the secondary beam varying in density in correspondence with the density variations of the primary exciting beam, means positioned between the primary source and the secondary electron emitter for density-varying the stream of primary electrons in accordance with control electromotive forces and for thereafter reducing their velocities so that they impinge upon the secondary electron emitter with reduced velocities whereby the efficiency of secondary electron emission is enhanced, and output means within the discharge device adjacent to the path of and electrically coupled to the secondary electron beam to extract amplified output energy therefrom corresponding to the control electromotive force.

5. An electron discharge device comprising a source of a primary electron beam, means adjacent the path of the beam for density-varying the beam in accordance with high frequency control waves, a retarding device positioned adjacent the path of the density varied beam for reducing the velocity of electrons of the density-

varied beam to an extent which permits all the primary electrons to continue in their original direction, an electron multiplier in the path of and responsive to the density-varied beam to produce a greatly augmented density-varied beam, and an output chamber resonant at the high frequency of the control waves having means including an opening aligned with the augmented beam to permit the beam to enter the chamber and to react with the electromagnetic field therewithin for extracting energy from the augmented beam.

6. An amplifier comprising an electronic device including means for producing a beam of high velocity electrons, means positioned adjacent the path of the high velocity electron beam for varying the velocities of the individual electrons at a point in their course in accordance with the instantaneous magnitude of a desired control force, an enclosure of electrically conducting material having an opening extending therethrough, the opening being directly in the path of and aligned with the electron beam to constitute drift space in which all the velocity-varied electrons proceed in the same general direction to produce a density-varied beam, a retarding means adjacent the path of the density-varied beam at a point subsequent to its emergence from the drift space for reducing the velocities of the electrons of the density-varied stream without halting any, a secondary electron emitting surface within the device and directly intercepting the density-varied stream and upon which the reduced velocity electrons impinge to produce an augmented stream of secondary electrons, means adjacent the path of the secondary electron stream for accelerating the secondary electron stream, and means adjacent to and electrically coupled with the secondary electron stream for extracting wave energy from the accelerated electron stream.

7. An electron discharge apparatus comprising a multiple stage electron multiplier having an electron emitting member in each stage, an input circuit and an output circuit therefor, electric field producing means connected to the input circuit for impelling a density-varied electron beam upon the first stage of the electron multiplier, means for establishing a magnetic field in the region of the multiplier and in a direction transverse to that of the electron paths therein, the electron emitting members of the multiplier having their principal planes parallel to each other in the magnetic field so that the interstage transit times of electrons are substantially independent of the positions on the electron surfaces at which the electrons emanate whereby the output current from the multiplier is density-varied in a manner substantially similar to that of the beam impinging upon the first stage.

RALPH V. L. HARTLEY.

Disclaimer

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Hereby enters this disclaimer to claim 3 of said patent.

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