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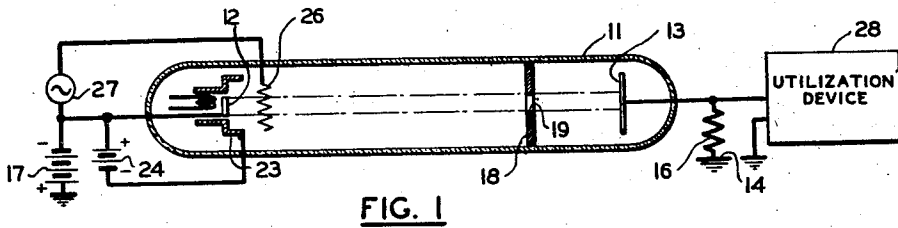
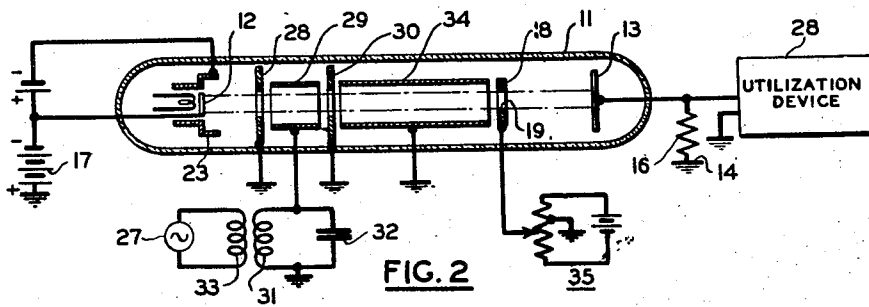
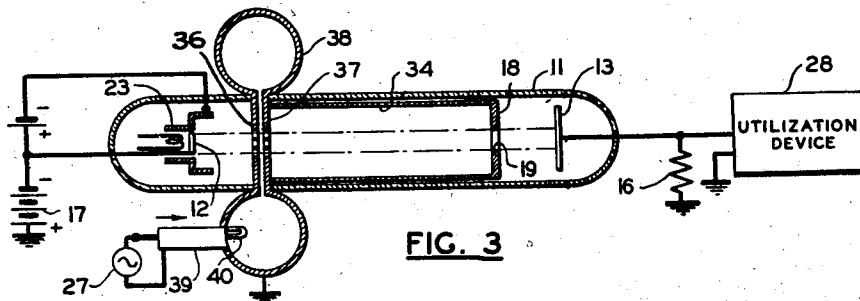
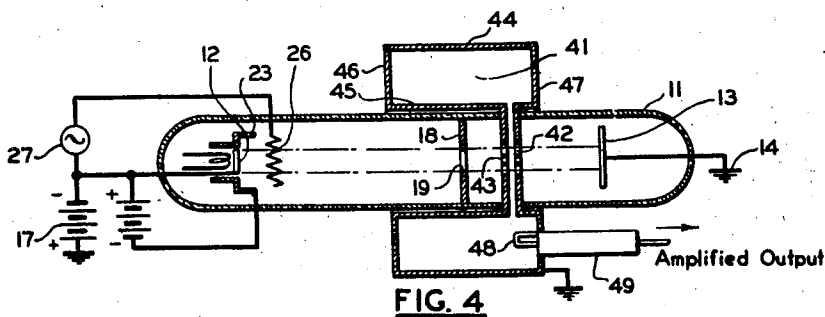
R. H. VARIAN ET AL

2,414,843

HIGH FREQUENCY APPARATUS UTILIZING ELECTRON DEBUNCHING

Filed June 16, 1943

2 Sheets-Sheet 1



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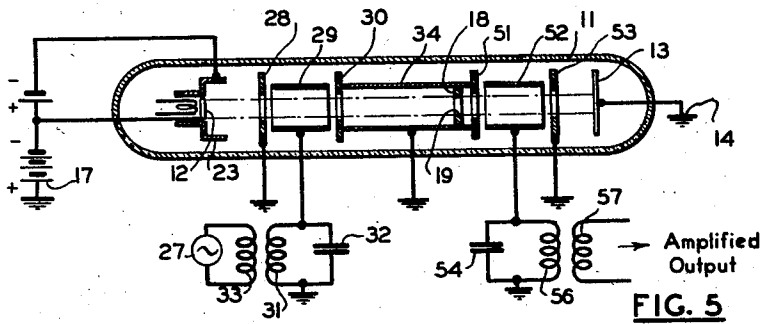
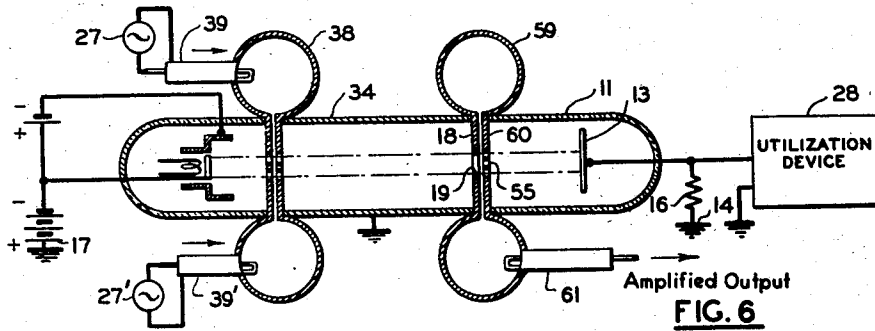
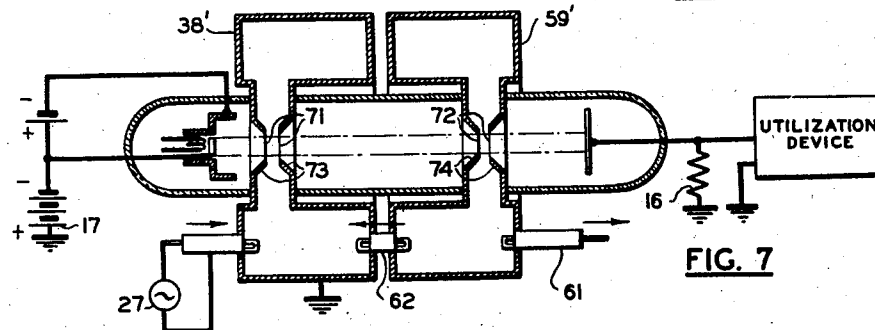
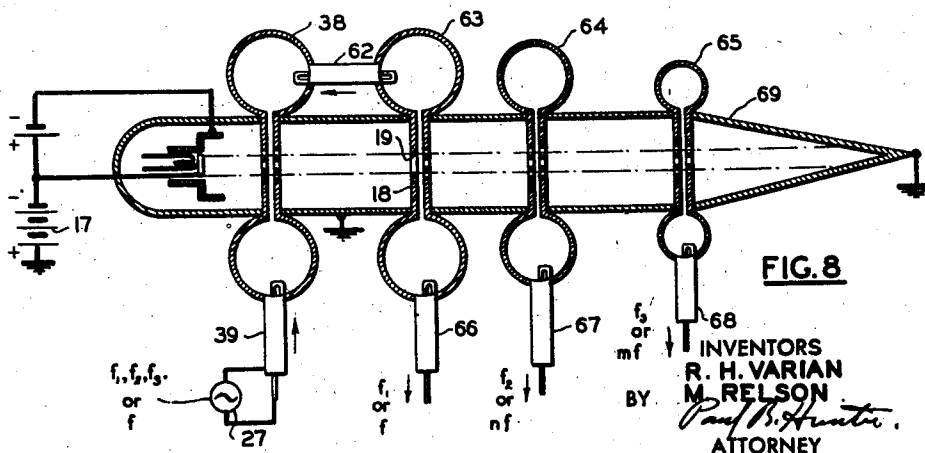
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Filed June 16, 1943

2 Sheets-Sheet 2



UNITED STATES PATENT OFFICE

2,414,843

HIGH-FREQUENCY APPARATUS UTILIZING
ELECTRON DEBUNCHING

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Application June 16, 1943, Serial No. 490,962

31 Claims. (Cl. 250—27)

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The present invention is related to the art including electron beam discharge tubes, and especially to those types of electron beam tubes in which the electron beam is grouped in some manner and energy is later abstracted from the beam.

In the prior art, two major forms of grouped electron beam tubes have been disclosed. In one type, shown in Haeff Patent No. 2,237,878, issued April 8, 1941, the grouping of an electron beam is performed by an electron space charge control grid to which suitable alternating potentials are applied for grouping the beam. A second type of grouping is effected in Varian Patent No. 2,242,275, issued May 20, 1941, and in the Hahn Patent No. 2,220,839, issued November 5, 1940, in which an alternating high frequency field is applied to the electron beam to vary the velocity of the electrons thereof. These velocity-varied electrons are then passed through a field-free drift space in which the faster electrons overtake the slower electrons, producing what may be termed "velocity grouping" of the electrons. The present invention is applicable to either type of electron grouping.

When an electron beam is projected for a relatively long distance, the beam has a slight tendency to disperse, due to the similar charges of all the electrons composing the beam which therefore repel one another. For a uniform ungrouped beam, this dispersion effect is relatively slight, because the passage of the beam through the highly but not completely evacuated enclosure produces positive ions which remain in the beam path because of their high inertia and neutralize the space charge of the beam electrons which otherwise would produce dispersion.

For a grouped, non-uniform electron beam, however, the dispersion or debunching of the groups is much greater than in the case of the uniform beam. This may be explained on the theory that the bunches, or groups, of electrons have much higher concentrations of like charges and therefore have more repelling action, approaching a tendency to "explode" the bunches; and also that the rapid passage of the bunches of electrons through the tube does not permit the neutralization of the space charge by the positive ions, which requires a finite time, of the order of 10^{-3} to 10^{-5} seconds, to attain an equilibrium condition. Thus the "exploding" tendency is increased. In fact, the electron dispersion is a direct function of the bunching or grouping of the beam.

Such debunching has been a harmful effect in

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prior art electron beam devices, since it limits the current densities which can be effectively used, and therefore limits the power capacity of these devices. However, this formerly harmful phenomenon is used here to advantage, permitting the former limitations of such beam devices to be overcome.

In the present apparatus, this phenomenon is utilized to provide a novel form of ultra high frequency detector, amplifier, oscillator, converter, or other type of device.

Accordingly, it is an object of the present invention to provide an improved ultra high frequency electron discharge device utilizing the phenomena of electron beam debunching or dispersion.

Another object of the present invention is to provide an improved form of ultra high frequency electron discharge device utilizing the dispersion of the electron beam in response to grouping of the beam, by passing the beam through a narrow aperture, whereby the portion of the beam which is dispersed is prevented from continuing along the tube, and the remainder of the beam is suitably utilized to supply a detected, amplified, or frequency multiplied version of the oscillations producing the grouping, or to produce sustained oscillations or to convert or mix applied oscillations.

Other objects and advantages will become apparent from the specification, taken in connection with the accompanying drawings, wherein the invention is embodied in concrete form.

In the drawings,

Fig. 1 is a diagrammatic cross-sectional view of an electron discharge tube according to the present invention, useful as a detector, together with a circuit therefor.

Figs. 2 and 3 are similar views of modifications of the device of Fig. 1.

Fig. 4 is a diagrammatic cross-sectional view of another form of electron discharge device and circuit therefor according to the present invention, useful as an amplifier.

Fig. 5 is a similar view showing a modification of the invention of Fig. 4.

Fig. 6 is a similar diagrammatic view of a further modification of the invention useful as an amplifier, detector, mixer, or frequency multiplier.

Fig. 7 is a similar view of another embodiment of the present invention used as an oscillator or self-excited mixer-converter.

Fig. 8 is a similar view of still another embodiment of the present invention useful as a frequency multiplier or multiplex amplifier.

In the drawings, Fig. 1 shows one form of the present invention, comprising an electron beam discharge tube having an evacuated, preferably insulating, envelope 11, in which is disposed a thermionic cathode or electron gun 12. At the opposite end of the evacuated envelope is a collector or target electrode 13, which is connected to ground at 14 through an output or load resistor 16. Cathode 12 is preferably maintained at a high negative potential by means of a suitable source indicated schematically by battery 17. If desired, of course, cathode 12 could be grounded, and anode 13 connected to a high positive potential source through the output resistor 16.

Disposed between the cathode 12 and collector 13 is an apertured plate or baffle 18 having a relatively small aperture 19 having an opening about the size of the beam. Cathode 12, of course, is heated by a suitable source of heating potential, not disclosed, and therefore emits thermionic electrons. These electrons are projected toward collector 13 by reason of the high potential existing between cathode 12 and collector 13. Preferably, the electron beam is collimated, as by means of a suitable electrode 23 energized from a direct current source 24, to form a uniform highly concentrated beam directed toward the opening 19 of plate 18. The beam is preferably chosen to have a very high current density, as it has been found that the efficiency and effectiveness of our device is related to the square of the current density. If desired, suitable focusing means may be used to increase this beam density to obtain higher efficiencies, but such focusing is not necessary.

Interposed between aperture 19 and cathode 12 is suitable means for producing grouping of the electron beam according to ultra high frequency waves which it is desired to demodulate or detect. In the present instance, this grouping means is indicated as a grid 26. The ultra high frequency waves to be demodulated are indicated schematically as a source 27 connected between grid 26 and cathode 12. As is described in the above Haefl patent, such an arrangement produces a charge density modulation of the electron beam so that the current density at certain portions of the beam will be different from the current density at other portions.

Originally, the aperture and beam are so arranged so that substantially all electrons of the unmodulated beam, in which practically no debunching occurs, just pass through aperture 19. Because of the debunching or dispersing phenomena discussed above, the bunches of electrons are "exploded" and the bunch becomes greatly enlarged, so that few electrons from the bunch will pass through aperture 19. However, practically all of the unbunched electrons will pass through aperture 19.

Since the modulation of the input wave from source 27 varies the beam current correspondingly, and thereby varies the debunching action which depends on the beam current density, the average electron current collected by collector 13 will vary in accordance with the modulation upon the electron beam and will therefore vary in accordance with the modulation of the modulated input wave derived from 27. This electron current flows through output resistor 16 and produces an output detected voltage which may be led to any suitable utilization device 28.

Fig. 2 shows a modification of the device of Fig. 1 in which the grouping of the beam is pro-

duced by velocity modulation in the manner disclosed in the above-mentioned Hahn patent, instead of by charge-density modulation as in Fig. 1. Thus here the focused electron beam from cathode 12 is passed successively through an apertured plate 28, a cylindrical electrode 29, and a second apertured plate 30. Plates 28 and 30 are grounded while cylinder 29 is connected to ground through an oscillatory circuit comprising a coil 31 and a condenser 32. The input wave from source 27 is coupled to the coil 31 by a second coil 33 forming a transformer therewith. In this manner, as disclosed in the Hahn patent, the velocities of the electrons of the beam are periodically varied. The velocity-varied beam is then projected through a field-free drift space provided by tube 34, which causes the velocity-modulated beam to become velocity-grouped. The grouped beam is projected through the aperture 19 of the plate 18 as in Fig. 1. The plate 18 may be grounded or positioned in the end of the drift tube 34, or it may be maintained at a suitable small potential difference with respect to ground, as by means of any suitable adjustable source of potential indicated at 35. Alternatively, plate 18 may be maintained at substantially the same potential as the cathode 12. The operation of this form of the invention is exactly the same as that of Fig. 1, and produces a detected or demodulated output voltage across resistor 16, which may be suitably utilized in the utilization device 28. The plate 18 of Fig. 1 may be grounded or maintained at a suitable potential as in Fig. 2.

Fig. 3 shows still another modification of the present invention utilizing the velocity grouping apparatus shown in the above-mentioned Varian patent. In this instance, the electron beam from cathode 12 is projected through the grids 36 and 37 forming a portion of the walls of a cavity resonator 38 tuned substantially to the frequency of the input wave derived from source 27. Resonator 38 is shown as toroidal in shape, but any suitable form of resonator adapted to interact with and velocity modulate an electron beam may be used. Resonator 38 is energized, by way of a suitable coupling line 39 and coupling loop 40, with the modulated ultra high frequency wave to be detected, and produces velocity modulation of the beam in the same manner as in Fig. 2. The drift tube 34, apertured plate 18, and collector 13 then produce a demodulated version of this input wave as a voltage across resistor 16, in the same manner as in the preceding figure. It will be noted that baffle plate 18 is shown fixed to the end of drift tube 34 in the modification of Fig. 3. However, it may be separately mounted and energized as in Fig. 2, if desired. Drift tube 34 may here be formed as a conductive coating on the wall of envelope 11, or may be located outside the envelope 11.

Instead of detecting the modulation upon the input signal 27, the principle of the present invention may be utilized to amplify the input ultra high frequency wave itself. Thus, Fig. 4 shows an amplifier using the grouping means of Fig. 1, and having a cavity resonator 41 provided on the side of plate 18 opposite cathode 12. Resonator 41 is formed in this instance with a pair of electron permeable grids 42 and 43 having a relatively close spacing. Grids 42 and 43 extend through the evacuated envelope 11 and are joined to the main body of resonator 41, formed by a pair of cylindrical concentric conductors 44 and 45 connected by respective annular end pieces 46

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and 47. The gap in inner conductor 45 across which grids 42 and 43 are connected is preferably placed near one end of inner conductor 45, although it may be located anywhere along the length of conductor 45, as desired. The grids 42, 43 may be capacitatively coupled to conductor 45 through the envelope 11, instead of conductively connected, as shown. If desired, plate 18 may be substituted for grid 43. Also, grid 42 may be replaced by a single apertured plate, or may be omitted. Any other suitable form of resonator could be used. The remainder of the apparatus of Fig. 4 is identical with that of Fig. 1, with the exception that collector 13 is directly grounded at 14.

In the operation of this form of the invention, the grouping of the electrons produces the same dispersion effects as in Fig. 1. By selecting the size of the aperture 19 so as to pass substantially only the very slightly grouped electrons, the electron beam which passes through the aperture 19 will have its grouping inverted with respect to the grouping produced by grid 26, since, as discussed above, those bunches of electrons which are most highly grouped by grid 26 will be dispersed most, and will be transmitted least through aperture 19. However, by the action of plate 18 and aperture 19, the grouping of the beam, although inverted, is intensified; that is, the charge density modulation of the beam is enhanced.

Accordingly, when this enhanced charge-density modulated beam passes through grids 42 and 43, ultra high frequency energy is given up by the beam to the field of the resonator 41. Because of the enhanced character of the charge-density modulation, an amplification effect is experienced, so that a higher amplitude output may be derived from resonator 41 by way of a suitable coupling loop 48 and output concentric transmission line 49. Thus, the present device may serve as an ultra high frequency amplifier. It will be noted that this utilization of the debunching effect provides improved mutual conductance and amplification over the device of the Haeff patent.

The device of Fig. 4 may serve to simultaneously amplify and detect, by connecting output resistor 16 to collector 13, as in Figs. 1 to 3.

Fig. 5 shows an amplifier according to the present invention utilizing the velocity-grouping and energy-abstracting apparatus of the Hahn patent mentioned above. It will be seen that Fig. 5 is essentially similar to Fig. 2, except that the electron beam passing through aperture 19 is then led successively through an apertured plate 51, a hollow cylindrical electrode 52, and an apertured plate 53 before striking the collector 13 which is grounded at 14. Cylinder 52 is connected to ground through a circuit tuned to the operating frequency and comprising, for example, a condenser 54 and a coil 56 to which is coupled a second coil 57 from which the amplified output of the apparatus may be derived.

Although plate 18 is illustrated here as being within and connected to the drift tube 34, it will be appreciated that it may be insulated therefrom and maintained at a suitable potential as in Fig. 2. Alternatively, plate 18 may be combined with plate 51 to form a single apertured plate. In this instance, cylinder 52 and the aperture in plate 53 should be somewhat smaller than indicated to interact successfully with the electron beam. The operation of this form of device is essentially the same as that described with respect to Fig. 4, and will produce an amplified output from coil 57.

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In place of the plate, cylinder and tuned circuit arrangement of Hahn shown in Fig. 5, there may be used respective cavity resonators 38 and 59 as shown in Fig. 6, which illustrates another form of amplifier according to the invention utilizing the velocity grouping and energy abstracting apparatus of the Varian patent mentioned above. Here the velocity grouping is produced in exactly the same manner as in Fig. 3. The velocity-grouped beam passing through the aperture 19 of plate 18 then passes through the gap 55 of resonator 59, and delivers ultra high frequency energy to this resonator 59.

As shown here, plate 18 forms part of a wall of resonator 59, and coacts with grid 60 to form gap 55 thereof. However, if desired, it may be positioned within the drift tube 34 as shown in Fig. 3, in which case a second grid or other apertured wall is provided for the resonator 59. Plate 18 may then be supplied with any suitable potential, as in Fig. 2.

In the device illustrated in Fig. 6, drift tube 34 forms a part of the evacuated envelope, although it may be positioned inside the envelope as in Fig. 3 or outside the envelope if desired.

Energy is fed to resonator 38 from source 27 by the coupling line 39, as in Fig. 3, and amplified energy may be abstracted from resonator 59 by a similar coupling line 61. In Fig. 6, collector electrode 13 is grounded through resistor 16, and the voltage across resistor 16 is led to utilization device 28, as in Figs. 1-3, whereby the device of Fig. 6 may also operate as a detector, as in Fig. 3.

It will be noted that the device of Fig. 5 superficially resembles a prior art form of velocity modulation device, in which a velocity-modulated electron beam is focused, in the absence of modulation, upon an apertured plate. The subsequent velocity modulation causes a longitudinal shift of the focus point of the beam, which therefore passes through the apertured plate to a lesser extent when modulated because it is then defocused at the aperture. This prior art device is thus responsive to the changes in velocity of the electrons due to velocity modulation.

It will be noted that any "bunch" of electrons produced by velocity grouping contains electrons of average velocity as well as electrons of lesser and greater velocity which have respectively drifted back upon or caught up with the average velocity electrons. Accordingly, this prior art device prevents the faster or slower electrons from passing through the aperture, but has no effect upon the average velocity electrons, which continue to pass therethrough, irrespective of whether they are part of the bunches or not.

The present invention operates upon an entirely different principle, in that the sorting action is responsive solely to the bunching or grouping of electrons, that is, is responsive only to the beam current density, and relies upon the dispersion effect which accompanies such bunching or grouping. This dispersion effect is a limitation upon the operation of the prior art device, as well as of the ordinary velocity modulation device, and prevents large power capacity for such devices. The present invention utilizes this former defect to good advantage.

In the present invention the average velocity electrons constituting the bunch, as well as the slower or faster electrons thereof, are substantially all dispersed and prevented from passing through the aperture due solely to the fact that they constituted the bunch originally. Also, the

electrons which are not formed in the bunch, including average velocity and slower and faster electrons, all pass through the aperture, so that it will be seen that the operation of the present device does not rely in any way upon the electron velocity and is distinctly different from that of such a prior art device. In addition, the present invention does not require focusing, which is a necessary feature of the prior art device.

A further distinction resides in the results produced. If we consider the oscillations produced in the catcher resonator of the ordinary velocity modulation device, illustrated by the Hahn or Varian patents mentioned above, as having a zero datum phase, the present invention will produce an output oscillation of a phase 180° different from that of the datum, due to the fact that what formerly were bunches are now rarefactions, and vice versa. In the prior art device just mentioned, however, the average velocity electrons pass through the aperture, while slower or faster electrons are blocked, so that the output phase will be 90° different from both that of the ordinary velocity modulation devices and of the present invention.

Furthermore, this prior art device is inherently of low mutual conductance, whereas the present invention has been found to have a relatively high mutual conductance or amplification, even compared with the usual velocity modulation device exemplified by the Varian and Hahn patents mentioned above.

Referring again to Fig. 6, resonator 38 is additionally provided with a second input line 39', to which is connected a second source of oscillations 27'. In this way the device of Fig. 6 may also operate as a mixer-detector, frequency converter, or superheterodyne first detector. Thus, if the source 27 is a source of modulated carrier wave, and the source 27' represents the output of a local oscillator having a frequency different from that of the carrier component of source 27, the voltage appearing across resistor 16 will then be an intermediate or beat frequency voltage. If the local oscillator wave of source 27' is of the same frequency as source 27, the detected modulation signal will appear across resistor 16, by homodyne detector action. The waves of sources 27 and 27' may be combined in resonator 38 in any other desired manner.

It will be clear that the devices of Figs. 1 and 2 can also be adapted to operate as mixer-detectors, by supplying an additional input thereto, as by connecting local oscillator source 27' in series with modulated wave source 27 in these figures.

The devices of Figs. 4, 5 and 6 are also adapted to operate efficiently as direct or driven frequency multipliers. The bunching of the beam produced in these devices is very sharp, especially when large input voltages are used, so that the variation of beam current at a particular fixed point along the path of the beam, which variation excites the output circuit, contains a large percentage of harmonics. Accordingly, the output circuit constituted by resonator 44, tuned circuit 54-56, or resonator 59 may be tuned to any desired harmonic, either even or odd, of the input wave, and substantial amounts of high frequency energy of this harmonic frequency may then be derived from the device.

The present invention may also be utilized to generate sustained oscillations. Thus, since any of the devices of Figs. 4, 5, or 6 will operate to amplify an input wave, they may be also utilized as regenerative oscillators by omitting the input

wave and supplying the input circuit with energy from the output circuit. This is illustrated in Fig. 7, applied to the amplifier device of Fig. 6, shown in slightly modified form. Here in place of grids for the resonators 38 and 59, small openings 71 and 72 in the walls of these resonators may be used. It has been found that, with small dense electron beams, it is not necessary to use grids, but mere openings substantially of the same size as the beam may be used effectively. Preferably these openings are formed in the small ends of frusto-conical wall portions, such as 73, 74. The resonators may be of the form shown at 38 and 59 of Fig. 6, or as shown at 38' and 59' in Fig. 7, or any other desired form. A feedback coupling line 62 couples the output resonator 59' to the velocity varying resonator 38'. In this way sustained oscillations will be set up in resonator 59' which may be supplied to the output line 61 as before.

It will be clear that in the devices of Figs. 4 and 5, also, a portion of the output energy may be fed back to the grouping portion of the system, that is, either to grid 26 or to cylinder 29, so as to provide self-sustained oscillations. In such a case, source 27 would be disconnected.

These devices may also operate as regenerative amplifiers if source 27 remains connected. In this case the feedback provided should be less than that required to form self-sustained oscillations.

The present invention may also be utilized as an autodyne or self-excited converter. This is also shown in Fig. 7, when the input wave 27 is at a slightly different frequency from that which would be generated by the regenerative action of the device. In such a case the voltage produced across the load resistor 16 will represent the beat frequency between the input wave and the self-sustained oscillation frequency. Such a converter is similar in effect to that of Fig. 6, but does not require an external source of heterodyne frequency corresponding to local oscillator 27'. In each of the modifications of Figs. 4 and 5, also, such an autodyne converter action may be obtained by providing a load resistor between collector 13 and ground, and by providing the regenerative feedback already discussed.

Other types of frequency multiplication may be provided by the present invention, as illustrated with respect to Fig. 8, which is adapted to operate either as a self-oscillatory frequency multiplier, as a driven frequency multiplier, or as a regenerative-driven multiplier. Firstly, considering the operation as a driven frequency multiplier, operation is similar to that described with respect to Fig. 7, but obtains a plurality of output harmonics simultaneously. Coupling 62 would then be omitted, and the frequency to be multiplied is applied to resonator 38 from source 27 by way of line 39. Coupled to the beam passing through the apertured plate 18 are a plurality of resonators 63, 64, 65, tuned to respective harmonics of the input frequency. Thus, resonator 63 may be tuned to the same frequency as the input wave, while resonators 64 and 65 may be tuned to higher harmonics. Since the grouped beam produced by the space-charge debunching effect contains a high percentage of harmonic energy, it will be seen that each of the resonators 63, 64, 65 will abstract energy at its corresponding frequency, so that from their respective output lines 66, 67, and 68 there may be obtained several different harmonics of the input energy.

As a self-oscillatory frequency multiplier the

input line 39 may be omitted and the feedback coupling 62 added. In such a case, resonators 38 and 63 operate as a self-excited oscillator, as discussed with respect to Fig. 7. This will produce a grouping of the beam in accordance with the self-resonant frequency of this oscillatory system. This beam may then be passed through the resonators 64 and 65, which will abstract energy therefrom at their corresponding frequencies. These resonators 64 and 65 may be tuned to any desired odd or even harmonic of the self-oscillatory frequency. The electron beam may thereafter be collected by suitable collector electrodes 69, which may be tapered to provide a large heat dissipating surface for the electron beam.

The apparatus of Fig. 8 may also operate as a regenerative driven frequency multiplier by supplying energy to resonator 38 by both lines 39 and 62.

The three types of frequency multipliers just described may also be utilized with the type of electron grouping illustrated in Figs. 4 and 5. Thus, in Fig. 4, the beam may be grouped through self-oscillatory, driven or regenerative-driven action, and a plurality of resonators may be successively coupled with the beam, each being tuned to a respective harmonic so that harmonic frequency energy may be derived simultaneously at a plurality of frequencies. Correspondingly, in Fig. 5 the beam may be similarly grouped, and a plurality of energy-extracting systems similar to plate 51, cylinder 52, and plate 53, may be successively coupled to the grouped beam, each cylinder of each such system being grounded through a circuit tuned to the particular harmonic desired.

The devices of Figs. 4 to 6 may also be adapted to amplify several different waves simultaneously. Thus, if source 27 is considered to represent a wave having several self-imposed frequencies, or to represent several sources in series, then a corresponding number of energy-extracting circuits, each tuned to one of said frequencies, may be coupled to the beam passing through aperture 19.

Such a device is illustrated in Fig. 8, if it now be assumed that the input 27 represents several frequencies and that the resonators 63, 64, 65 are tuned respectively to these frequencies. In this manner, we have several different frequency input waves amplified simultaneously by interaction of a plurality of output circuits with a single electron beam. Feedback 62 may supply regenerative action, if desired, or may be omitted. A similar system may be set up, utilizing the electron grouping system of Fig. 4 or Fig. 5.

It is to be noted that modulation may also be effected in any of the forms of the invention described above, either by interposing a further charge-density modulating electrode energized by the modulation signal between the cathode and the grouping arrangement, or by varying the focus of the beam (if utilized) in accordance with the modulating signal, or by varying the potential of the electrode 23 by this signal.

Thus, it will be seen that we have described improved forms of ultra high frequency apparatus utilizing advantageously the hitherto harmful debunching effect of the electron beam for purposes of detection, amplification, generation, frequency multiplication, frequency converting, mixing, etc.

Since many changes could be made in the

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

What is claimed is:

1. A high frequency electronic detector apparatus comprising means for producing an electron stream, a collector electrode for collecting the electrons of said stream, a load connected to said collector electrode, means comprising a cavity resonator excited by a modulated high frequency wave and having a pair of electron permeable electrodes disposed in the path of said electron beam, for velocity modulating the electrons of said beam in accordance with said wave, means defining a field-free drift space disposed around said beam to permit said velocity-modulated electrons to become bunched, and an apertured plate having its aperture in the path of said electron beam, whereby said plate serves to prevent debunched electrons from reaching said collector electrode and thus effects variations in the current reaching said collector in accordance with the changes in the amplitude of said velocity modulation.

2. A high frequency detector apparatus comprising means for producing an electron stream, a source of modulated high frequency waves, means including a cavity resonator energized from said source and having a pair of electron permeable walls disposed in the path of said beam for velocity modulating the electrons of said beam, means providing a field-free drift space surrounding the path of said velocity-modulated electrons to cause velocity grouping thereof, a collector electrode for collecting the electrons of said beam, a load connected to said electrode, and means comprising an apertured plate disposed in the path of said velocity-grouped beam for preventing debunched electrons of said beam from reaching said collector electrode, whereby the current supplied to said load represents a demodulated version of said modulated wave.

3. High frequency electron discharge tube apparatus comprising means for producing a beam of electrons, means for producing grouping of the electrons of said beam in accordance with a modulated wave, a collector electrode for collecting the electrons of said beam, and means comprising an apertured plate having the aperture thereof located in the path of said beam for preventing debunched electrons from reaching said collector electrode, whereby the electron current flowing thereto represents a demodulated version of said modulated wave.

4. High frequency electron discharge tube apparatus comprising means for producing a beam of electrons, means for grouping said electrons in accordance with a modulated wave, means for collecting said grouped electrons, and means located in the path of said beam for preventing debunched electrons of said beam from reaching said collector means, whereby the electron current collected by said electrode will represent a demodulated version of said modulated wave.

5. High frequency electron discharge tube apparatus comprising means for producing an electron stream, an apertured plate located in the path of said stream and adapted to pass said stream in the absence of grouping thereof, means for grouping said electron stream in accordance

with a modulated high frequency wave, and means responsive to the electrons passing through said apertured plate for producing a demodulated version of said wave.

6. High frequency electron discharge tube apparatus comprising means for producing an electron stream, a source of modulated high frequency waves, means energized from said source for grouping the electrons of said beam in accordance with said waves, means for obstructing passage of debunched electrons of said grouped stream, and means responsive to the remaining electrons of said stream for producing a detected version of said modulated wave.

7. An ultra high frequency apparatus comprising means for producing a concentrated beam of electrons, means for varying the density of said beam in accordance with a modulated high frequency wave, and means responsive to lateral spreading of the electrons of said beam due to mutual repulsion for producing a detected version of said modulated wave.

8. A high frequency amplifier apparatus comprising means for producing an electron stream, means for collecting said electrons, means comprising a cavity resonator energized with an oscillating electromagnetic field and having a pair of electron permeable grids disposed in the path of said beam, for producing velocity modulation of the electrons of said beam, means defining a field-free drift space wherein said velocity-modulated electrons become bunched, means comprising a second cavity resonator having a pair of electron permeable grids disposed in the path of said electron beam between said drift-space defining member and said collector means, for abstracting energy from said bunched electron beam, and means comprising an apertured member disposed in the path of said beam for preventing debunched electrons from entering said second resonator and being collected by said collector means.

9. High frequency electron discharge tube apparatus comprising means for producing an electron stream grouped in accordance with a high frequency wave, means for obstructing passage of debunched electrons of said stream, and means responsive to the non-obstructed electrons of said stream for producing an amplified version of said wave.

10. High frequency electron discharge tube apparatus comprising means for producing an electron stream, means for grouping said stream in accordance with a high frequency wave, and means responsive solely to non-debunched electrons of said stream for producing an amplified version of said wave.

11. High frequency electron discharge tube apparatus comprising means for producing an electron stream, means for producing grouping of the electrons of said stream in accordance with a high frequency wave, means for abstracting amplified high frequency energy from said grouped stream, and means for preventing debunched electrons of said grouped stream from interacting with said energy abstracting means whereby an increased amplification of said wave may be obtained.

12. An ultra high frequency apparatus comprising means for producing a concentrated beam of electrons, means for varying the density of said beam in accordance with an input wave, and means responsive to lateral spreading of the electrons of said beam due to mutual repulsion

for producing an amplified version of said input wave.

13. High frequency electron discharge tube apparatus comprising means for producing an electron stream, means for grouping said electron stream in accordance with a modulated wave and a local oscillator wave, means comprising an apertured plate located in the path of said beam for obstructing passage of debunched electrons of said grouped beam, and means responsive to the remaining electrons of said beam for producing a modulated intermediate frequency output from said apparatus.

14. High frequency electron discharge tube apparatus comprising means for producing an electron stream, a source of modulated high frequency wave, a source of local oscillations, means for grouping the electrons of said beam in accordance with said wave and said oscillations, means for collecting said electrons, means for preventing said collecting means from collecting debunched electrons of said stream, and means responsive to the remaining electrons of said stream for producing a modulated intermediate frequency output from said device.

15. High frequency apparatus comprising means for producing an electron stream, a source of high frequency modulated wave having a predetermined carrier frequency, a source of local oscillator wave having a frequency equal to said predetermined frequency, means for grouping said electron stream in accordance with both said waves, means for obstructing passage of debunched electrons in said grouping beam, and means responsive to the remaining electrons of said beam for producing a detected output from said apparatus.

16. High frequency apparatus comprising means for producing an electron stream, means for producing grouping of the electrons of said stream in accordance with a high frequency wave, means for abstracting high frequency energy from said grouped stream, means for at least partially energizing said grouping means by a portion of said abstracted energy, and means for preventing debunched electrons of said grouped stream from interacting with said energy abstracting means.

17. High frequency oscillation generating apparatus comprising means for producing an electron stream, means for grouping the electrons of said stream, means for abstracting high frequency energy from said grouped stream, means for energizing said grouping means from said abstracted high frequency energy, and means for preventing debunched electrons of said grouped stream from interacting with said energy abstracting means, whereby sustained ultra high frequency oscillations may be produced.

18. High frequency electron discharge tube apparatus comprising means for producing an electron stream, a source of modulated high frequency wave, means energized by said source for grouping said electron stream in accordance with said wave, means for obstructing passage of debunched electrons of said grouped beam, means for abstracting high frequency energy from the remaining electrons of said beam at a frequency different from that of said wave, means for additionally energizing said grouping means by said abstracted energy, and means responsive to said remaining electrons for producing a modulated intermediate frequency output from said apparatus.

19. High frequency apparatus comprising

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means for producing an electron stream, means for grouping said electron stream in accordance with a modulated high frequency wave having a predetermined carrier frequency, means for abstracting energy of said predetermined frequency from said beam, means for energizing said grouping means in accordance with said abstracted energy, and means for detecting said electron beam to provide a demodulated output from said apparatus.

20. High frequency apparatus comprising means for producing an electron stream, means for producing grouping of the electrons of said stream in accordance with a high frequency wave, means for abstracting high frequency energy from said grouped stream having a frequency harmonically related to said wave, and means for preventing debunched electrons of said grouped stream from interacting with said energy abstracting means.

21. High frequency apparatus comprising means for producing an electron stream, means for producing grouping of the electrons of said stream in accordance with a high frequency wave, means for abstracting high frequency energy at a plurality of frequencies harmonically related to the frequency of said wave from said grouped stream, and means for preventing debunched electrons of said grouped stream from interacting with said energy abstracting means.

22. High frequency apparatus comprising means for producing an electron stream, means for producing grouping of the electrons of said stream in accordance with a plurality of high frequency waves having differing frequencies, means for abstracting high frequency energy of said plurality of frequencies from said grouped stream, and means for preventing debunched electrons of said grouped stream from interacting with said energy abstracting means.

23. High frequency apparatus comprising means for producing an electron stream, a hollow cavity resonator having a pair of electron permeable grids disposed in the path of said stream, means for energizing said resonator with a plurality of high frequency waves of differing frequencies whereby velocity modulation of said stream at said differing frequencies is produced, means for causing said velocity-modulated stream to become bunched, and means for abstracting energy of said differing frequencies from said bunched stream, said last-named means comprising a plurality of hollow cavity resonators tuned respectively to said differing frequencies and adapted to be energized by said bunched stream.

24. High frequency electron discharge tube apparatus comprising means for producing an electron stream, means for collecting said electrons, means comprising a cavity resonator having a pair of electron permeable grids disposed in the path of said beam for producing velocity modulation of the electrons of said beam, means defining a field-free drift space wherein said ve-

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locity-modulated electrons become bunched, means comprising a second resonator for abstracting energy from said bunched electron stream, and means positioned just before said second resonator for preventing debunched electrons of said stream from entering said second resonator.

25. High frequency electron discharge tube apparatus comprising means for producing an electron stream, means for collecting said electrons, means energized by a high frequency wave for producing velocity modulation of the electrons of said beam, means defining a field-free drift space wherein said velocity-modulated electrons become bunched, means for abstracting energy from said bunched electron beam, and means positioned just before said abstracting means for preventing debunched electrons from interacting with said energy abstracting means.

26. High frequency apparatus comprising means for producing an electron stream, means for producing grouping of the electrons of said stream, means for abstracting energy from said grouped stream, and means positioned just before said abstracting means for preventing debunched electrons of said grouped stream from interacting with said energy abstracting means.

27. High frequency apparatus comprising means for producing an electron stream grouped in accordance with a high frequency wave, means for obstructing passage of debunched electrons of said stream, and means for utilizing the non-obstructed electrons of said stream.

28. High frequency apparatus as in claim 27, further including means for modulating said stream in accordance with a modulation signal, and wherein said utilizing means comprises means for abstracting modulated high frequency energy from said stream.

29. An ultra high frequency apparatus comprising means for producing a concentrated beam of electrons, means for varying the density of said beam, and means responsive to lateral spreading of the electrons of said beam due to mutual repulsion, for abstracting energy from said density-varied beam.

30. An ultra high frequency device comprising means for producing a concentrated beam of electrons, means for varying the density of said electrons, an output circuit coupled to said beam, and means for varying the action of said electrons in said circuit in accordance with the lateral spreading of said beam due to mutual repulsion of the electrons thereof.

31. A method of operating ultra high frequency electron beam apparatus comprising the steps of producing a concentrated beam of electrons, varying the density of said beam, and abstracting energy from said beam in accordance with the lateral spreading of said beam due to mutual repulsion of the electrons thereof.

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