Oct. 30, 1951 J. H. COLEMAN 2,573,247

MEANS FOR SIGNAL AMPLIFYING AND MIXING
UTILIZING SPACE CHARGE NEUTRALIZATION

Filed Jan. 3, 1949 2 SHEETS—SHEET 1

Fig. 1.

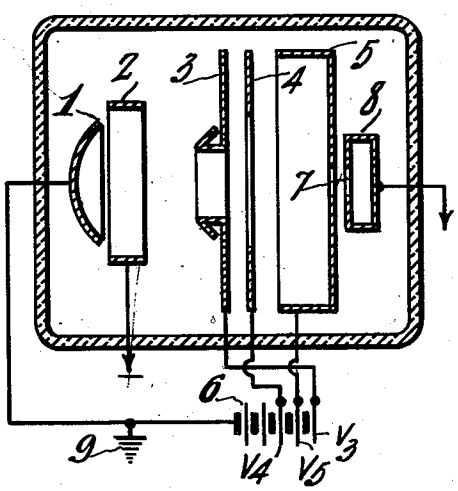


Fig. 2.

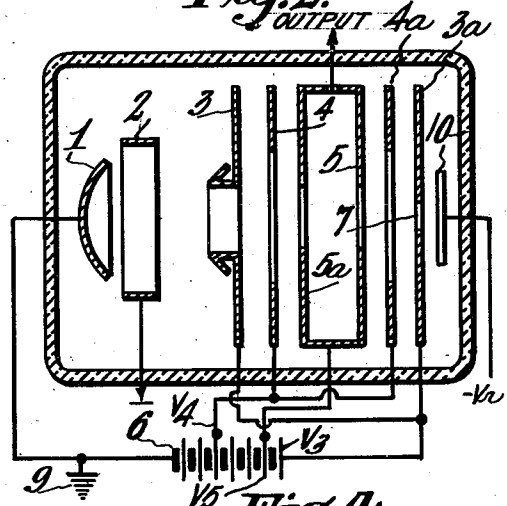


Fig. 4.

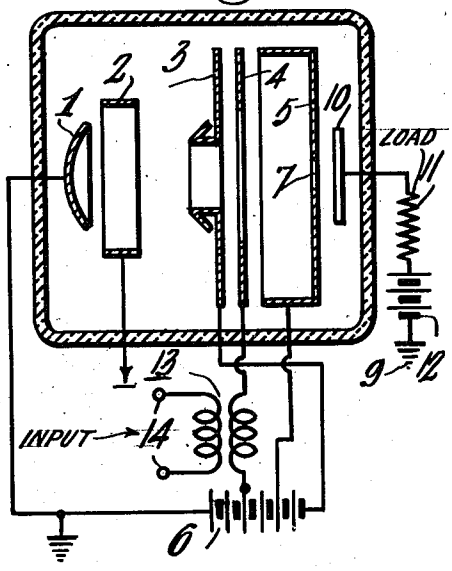
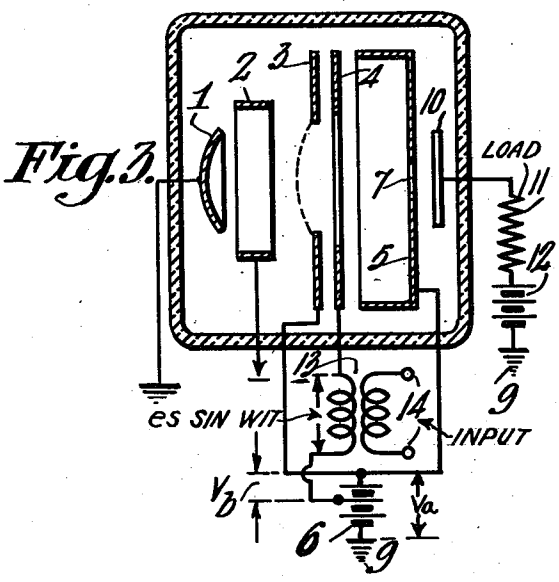


Fig. 3.



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MEANS FOR SIGNAL AMPLIFYING AND MIXING
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Filed Jan. 3, 1949 2 SHEETS—SHEET 2

Fig. 5.

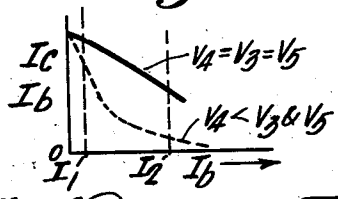

Fig. 6.

Fig. 7.

Fig. 8.

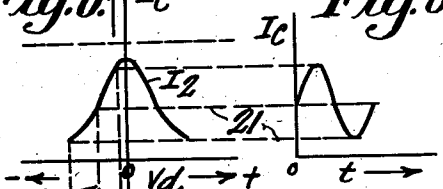

Fig. 9.

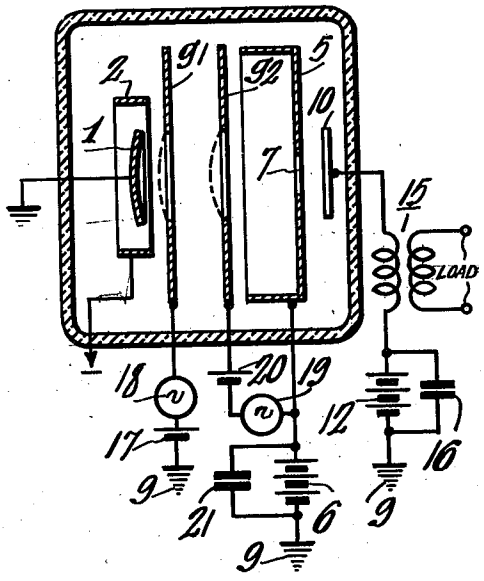

Fig. 10.

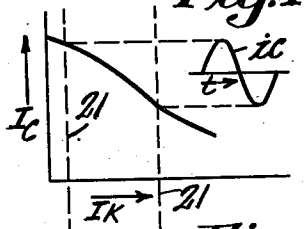

Fig. 11.

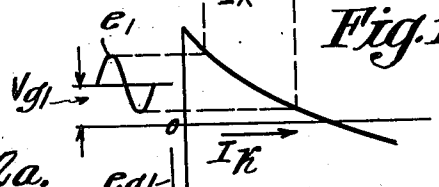

Fig. 12a.

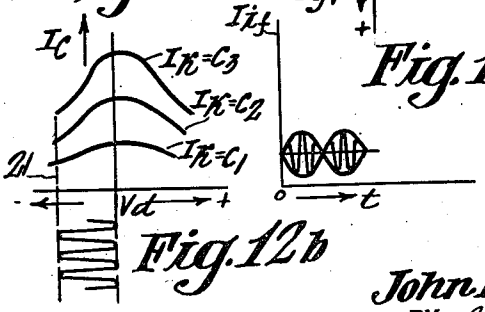

Fig. 12b

Fig. 12c.

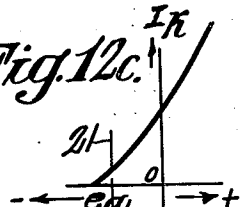

Fig. 12d.

Fig. 12e

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UNITED STATES PATENT OFFICE

2,573,247

MEANS FOR SIGNAL AMPLIFYING AND MIXING UTILIZING SPACE CHARGE NEUTRALIZATION

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Application January 3, 1949, Serial No. 68,947

11 Claims. (Cl. 315—16)

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This invention relates generally to high current electron gun devices and systems and more particularly to the combination of such devices in apparatus such as oscillators, amplifiers, modulators and mixers wherein the density of an electron beam is varied, that is, the beam is concentrated and dispersed by variations of space charge neutralization and with negligible accompanying electron velocity variations.

In applying electron guns to microwave devices and their associated circuits, it has been most desirable in the past that the electron beam be fine, dense and concentrated. These qualities have been somewhat improved by the use of various electron focussing devices and particular forms of field-free arrangements, none of which are similar, individually or in combination, with the methods and apparatus disclosed herein and set forth in the appended claims. U. S. Patent 2,111,940 discloses, for example, a focussed electron beam in a metal envelope that purports to establish a field-free space. The beam is shielded from extraneous fields only by the metal envelope, as in a wave-guide structure, but it is definitely stated that "the ionization potential of the gas filling" is "not reached" (lines 20, 21, column 1, page 3). The space between electrode 5 and chamber wall 2 in this patent is, therefore, not field-free in that the beam itself produces a field as it consists of charged particles. In U. S. Patent 1,565,873, is disclosed the neutralization of the space charge throughout the whole general space through which passes "a period of cathode rays." There is no suggestion in this patent that a heavy current beam, that is being focussed at a point, is concentrated by the trapping of ions within the beam itself. Furthermore, in the devices disclosed herein the gas pressures are not critical.

However, in neither of the reference patents cited is there disclosed the concentration of the beam and the dispersion of the beam as a step in the method of using the phenomenon of ion trapping for new and useful purposes of generating, modulating, amplifying, and mixing of currents. Likewise, the patents cited do not disclose the structures described and claimed herein.

In copending application filed on December 31, 1948, in the name of Ernest G. Linder, Serial No. 68,605, there is disclosed and claimed the method of and apparatus for controlling the density of an electron beam and the combination of the controlled beam with microwave oscillator and modulator structures.

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This control of the density of the beam is accomplished by establishing a field-free region in the medium through which the beam passes, whereby the ions, formed by the ionization of the residual atoms in the gas of the medium by collisions with the electrons of the beam, are trapped within the beam and neutralize the space charge therein. Control is thereby had of the size of the beam. It may be reduced or dispersed at its approaches the apertures in the resonant cavity of an oscillator or the aperture in the collecting structure of a modulator or amplifier. Means is also provided in said copending system for employing a magnetic field to assist in concentrating the beam.

When the improved beam device is combined in a structure, such as an oscillator, the efficiency of the system is increased by the improved beam concentration, thus providing for a larger percentage of the electrons to pass through the restricted aperture in the resonant cavity of the oscillator. Also, dispersion in the drift space of the oscillator is reduced, with attending decrease in debunching. When the improved beam device is combined with a modulator or amplifier structure, the efficiency of the device is increased because the beam is denser and finer and smaller apertures may be used. With such apertures and fine beams, a small dispersion results in a large proportion of the electrons not passing through the aperture, which is a measure of the efficiency of the device as an amplifier or modulator.

The present invention is an improvement over that disclosed in the said application in that there is provided herein a separate electrode to vary or control the space charge neutralization provided by trapping the positive ions in the electron beam and hence the degree of fineness or dispersion of the beam. Were an accelerating electrode used for this purpose, as disclosed in said application, the currents in the varying or modulating circuit would be larger and there would be less freedom of choice in the selection of the various voltages for different geometries of construction and arrangements of the involved devices.

In this application the invention is also disclosed in combination with the structures of amplifiers, oscillators and mixers of currents of different frequencies, to obtain a current of an intermediate frequency. In the latter embodiment of the invention there is provided the combination in the one device of two methods of beam modulation by the use of two separate electrodes to accomplish mixing, one of the electrodes

being a control grid adjacent the cathode, and the other electrode providing control of space charge neutralization within the field-free space.

Among the objects of the invention is to provide a method of and apparatus for producing a high current density electron beam.

Another object of the invention is to provide a method of and apparatus for controlling the density of an electron beam.

Another object of the invention is to provide a field-free space in the region of an electron beam to neutralize the space charge within the beam.

Another object of the invention is to control the density of an electron beam as it approaches an aperture, to control the proportion of electrons that pass therethrough and thereby accomplish current modulation.

Another object is to provide improved methods of and means for controlling the space charge neutralization of an electron beam device and system.

A further object is to provide improved methods of and means for generating, amplifying or mixing or modulating electric currents by controlling space charge neutralization in an electron beam device or system.

Another object is to provide improved methods of and means for controlling space charge neutralization in an electron beam device with negligible accompanying electron velocity variation.

Another object of the invention is to control the density of an electron beam in accordance with the frequency characteristics of two electric currents and thereby accomplish the mixing of the currents to produce a current of an intermediate frequency.

Other objects will be apparent from the description of the invention as hereinafter set forth in detail and from the drawings made a part thereof in which Figure 1 is a diagrammatic sketch of arrangement of the basic elements of the invention; Figure 2 is a diagrammatic sketch of the elements of Figure 1 applied to a reflex-klystron; Figure 3 is a diagrammatic sketch of another embodiment of the invention applied to a modulator structure; Figure 4 is a diagrammatic sketch showing the application of modulation to the arrangement disclosed in Figure 1; Figure 5 is a plot showing the relation of (1) values of the ratio of collected current to beam current to (2) the values of the beam current in the circuit set forth in Figure 3; Figures 6, 7 and 8 are associated characteristic curves of the arrangement shown in Figure 3; Figure 9 is a diagrammatic sketch of a further embodiment of the invention applied to a signal mixer; Figures 10 and 11 are associated characteristic curves of the arrangement shown in Figure 9; and Figures 12*a*, 12*b*, 12*c*, 12*d* and 12*e* are associated characteristic curves of the arrangement shown in Figure 9.

Similar reference characters are applied to similar elements throughout the drawings.

Referring to Figure 1, numeral 1 represents a spherical cathode, as a source of a focussed electron beam. Additional focussing may be obtained by a focussing ring or electrode 2 positioned near the periphery of cathode 1 and maintained at an appropriate negative potential, in any conventional manner.

The electrons in the beam are projected towards and accelerated by electrodes 3, 4 and 5, which are maintained at positive potentials V_3, V_4 and V_5 respectively, by electric source 6. In the center of electrode 5, and in the axis of the beam, is aperture 7. Aligned with aperture 7 is a

Faraday cage 8, which is connected to suitable conventional indicating instruments, not shown, to observe the currents of the beam passing through aperture 7. The device may be grounded as at 9.

In operation, electrons in the beam are accelerated by the electrodes 3, 4 and 5 toward the aperture 7 and after passing therethrough are collected by Faraday cage 8. The amount of current collected under the influence of the various potentials placed upon electrodes 3, 4 and 5 is a measure of the fineness or the density of the beam or its dispersion.

The spherical cathode 1 and focussing electrode 2 should produce a beam converging at aperture 7 into a fine focus. However, a space charge is built up within the beam due to the like charges of the electrons constituting the beam and the beam electrons collide with the residual molecules of the medium causing ionization of molecules of the medium and thereby creating additional electrons. The electrons created by the ionization of the medium are of relative low velocity, are repelled by the electrons in the beam, and drift away from the beam. The ions, being charged positively, are attracted to and trapped within the beam where they neutralize the space charge created by the charges of electrons in the beam itself.

Without the electrode 4, the field outside the substantially field-free space between electrodes 3 and 5 would extend through the aperture or window in electrode 3, causing ions in the field-free space to drift towards the cathode 1. The presence of electrode 4 with its positive potential effectively closes the aperture in electrode 3 insofar as field penetration from without and ion drift from within the free-field space is concerned. A grid structure across the aperture in electrode 3 would operate similarly, but would have the disadvantage that considerable grid current would result, whereas electrode 4 draws negligible current.

There is thus provided a field-free region through which the beam passes without the dispersion that would otherwise occur and with negligible change in the velocities of the electrons. It is apparent, then, that with variations of the forces establishing the field-free space, the configuration of the said space may be varied and thus the density of the beam may be varied. The beam may thus be concentrated to its optimum fineness or dispersed and thereby control may be had of the proportion of the electrons of the beam that pass through aperture 7. Modulation or amplification is thus provided.

The embodiment of the invention in various structures to obtain the desired results will be disclosed hereinafter, including the embodiment of the invention to provide the mixing of currents of different frequencies to obtain a current of an intermediate frequency.

In practice, it is preferable in general that the potential placed on electrode 3 should be higher than that on electrode 5 and the potential placed on electrode 4 should be less than that on electrode 5. The magnitudes of these potentials, however, depend on the geometry of the device. In the arrangement tested, the potentials on electrodes 3, 5 and 4 were: V_3=300 volts, V_5=290 volts and V_4=280 volts.

Referring to Figure 2, the invention is combined with a reflex-klystron structure. Here, the electrode 5 of Figure 1 has added to it the side wall 5*a* to form the resonant cavity. Elec-

trodes 3a and 4a are added to create a field-free drift space between wall 5 of the resonant cavity and repeller electrode 10, which is connected to a source of negative potential (—Vr), and is substituted for the Faraday cage 8. Electrode 4 controls the field penetration at the aperture in electrode 3 and therefore controls the configuration of the field-free region, as previously described.

The modified reflex-klystron operates in the conventional manner, as is well known in the art, but with greater efficiency because the electron beam is not dispersed by the otherwise present space charge, especially in the drift space where debunching is prevented.

Referring to Figure 3, the invention is incorporated into a modulator structure. Here, the electron beam is supplied by cathode 1 and the electrons thereof are accelerated by electrode 3, which is in the form of a grid and is positioned in the axis of the beam. The electrons are also accelerated by electrodes 4 and 5. The electrons pass through aperture 7 in electrode 5 and are collected by the electrode 10. Load resistance 11 and electric source 12 are connected in series with each other between electrode 10 and ground 9. Modulating electrode 4 is connected to one terminal the secondary of transformer 13, the primary of which is connected to the source 14 of the modulating current. The other terminal of the secondary of transformer 13 is connected through source 6 to ground 9. Electrodes 3 and 5 are connected to source 6. Electrode 4 is biased as to electrodes 3 and 5 by connecting electrodes 3 and 5 to the end positive pole of source 6 and electrode 4 is connected to an intermediate positive pole of source 6. The potentials of electrodes 3 and 5 above ground is designated as V_a and the bias potential of electrode 4 below electrodes 3 and 5 is designated as V_b. The electric potentials induced in the secondary of transformer 13 are designated as $es \sin \omega t$.

In operation, if the potential on electrode 4 be held constant, biased as to electrodes 3 and 5 by V_b, the beam would be maintained at its optimum density. However, when the potential on electrode 4 is varied by the potentials applied from source 14 through transformer 13, the beam is concentrated and dispersed according to the characteristics of source 14. This results in a modulated current being collected by electrode 10. It is apparent that the same effect on the beam could be had by varying the potential on grid 3 with respect to the potential on electrode 5. This may be accomplished by connecting the secondary of transformer 13 between grid 3 and source 6. It is also apparent that with this latter arrangement, a comparatively weak signal impressed upon electrode 3 may control the density of the beam and provide an amplification of the signal through the load resistance 11.

The arrangements shown in Figure 4 are the same as those in Figure 1 except that electrode 4 has impressed upon it the modulating voltage $es \sin \omega t$ through transformer 13 and a load circuit, including load resistance 11, electric source 12 and ground 9, is substituted for Faraday cage 8 and associated indicating instruments, not shown, as heretofore described.

The construction and circuit arrangements of Figure 4 are similar to those in Figure 3 except that the aperture in electrode 3 in Figure 4 is open whereas electrode 3 in Figure 3 is in the form of a grid. There is thus provided in Figure 4 a new type of amplifier which depends in its operation on controlling the density of a comparatively large beam current by a small current that affects the space charge in a region bounded by an open electrode with aperture at the point of entrance of the beam into the said region and by a restricted aperture in the electrode at the exit point of the region.

The operating characteristic curves are shown in Figures 5, 6, 7 and 8. In Figure 5 is plotted the relation between (1) the ratio of current flowing to collector 10 (I_c) to the total beam current (I_b) to (2) the total beam current (I_b). The solid line in Figure 5 shows this relation when $V_4=V_3=V_5$ and the dotted line in Figure 5 shows this relation where V_4 is less than V_3 and V_5.

It will be noted from these curves that the ratio of I_c to I_b decreases for increases of I_b. This is apparently due to a decrease in effective trapping.

When the potential on electrode 4 is reduced with respect to electrodes 3 and 5, the region through which the beam passes is less field-free and the positive ions, created by ionization of the medium, are swept out of this region, with attending building up of space charge, which in turn causes the beam to be dispersed.

The coincidence of the solid curve with the dotted curve at low values of I_b, when the beam dispersion due to space charge is negligible, indicates that the focussing of the electron optical system is not disturbed by the variations of potentials placed on electrode 4.

In Figure 6 is plotted the relation between the current collected by electrode 10 (I_c) to differences in potentials between electrode 4 and electrodes 3 and 5 (V_d) for the two beam currents I_1 and I_2, Figure 5. The value of I_c for I_1 (dotted curve) in Figure 6 is practically constant over the complete range of V_d, which indicates that the defocussing of the beam is negligible, as there are no space charge limitations. The solid curve (I_2) indicates the actual change in current density due to the variations in the potentials placed on electrode 4 relative to the potentials placed on electrodes 3 and 5.

The effect of applying a signal voltage ($es \sin \omega t$) on electrode 4 is shown graphically by Figures 6, 7 and 8, the ordinate axis of Figure 6 being aligned with the ordinate axis of Figure 7 and the abscissa axis of Figure 6 being aligned with the abscissa axis of Figure 8. Values of the varying voltage ($es \sin \omega t$), biased by the value V_b (Figure 7), are projected by projection lines 21 onto Figure 6 and the corresponding value of I_c are projected onto Figure 8 (I_c versus time) to obtain the modulated values, I_b.

Referring to Figure 9, the invention is shown incorporated into a mixer or an arrangement for converting currents of two frequencies to a different frequency, called the intermediate frequency. Here, a focussed electron beam is produced by spherical cathode 1, with supplementary focussing electrodes 2, as previously disclosed. The beam passes through control grid g_1 and accelerating grid g_2, through the cavity formed by electrode 5, and through the aperture 7 of electrode 5. The electrons are collected by electrode 10. The load circuit consists of primary of transformer 15, electric source 12 and ground 9. A capacitor 16 is connected in parallel with source 12 to by-pass the radio frequency currents. The output of the device is the secondary of transformer 15.

Control grid g_1 is biased above ground or neutral potential by electric source 17 and has im-

pressed upon it varying potentials from the source 18 of the first frequency current. Electrode 5 has impressed upon it a positive potential from electric source 6. The potentials impressed upon accelerating grid g_2 includes a positive potential from source 6, varying potentials from the source 19 of the second frequency current and a potential from source 20, which biasses grid g_2 with respect to electrode 5 and collector 10. A capacitor 21 is connected in parallel with source 6 to by-pass the radio frequency currents. The potentials of sources 12 and 6 are substantially equal to each other.

The operation of the device is explained graphically by the characteristic curves in Figures 10, 11, 12*a*, 12*b*, 12*c*, 12*d*, and 12*e*. The effect of potential changes on grid g_1 alone is observed by maintaining constant the potential on grid g_2. There being no change in potential of source 6, the bias of grid g_2 with relation to electrode 5 is constant.

A varying potential e_1, that of the first frequency current source 18, is placed upon grid g_1, with a biasing potential from source 17. The value of the current in the beam passing between the grid g_2 and the electrode 5, I_k, is determined by the usual relation $\Delta i_k = G_{m1} \Delta e_{g1}$, where G_{m1} is the transconductance of the device. The plot of this relation is shown in Figure 11. The relations between the values of the current I_k and the current collected by electrode 10, I_c, is observed and is plotted in Figure 10. It is thus possible to obtain the values of current I_c for variations of e_{g1} by projecting (lines 21) corresponding values of I_k determined from the curve in Figure 11 to equal values of I_k in Figure 10, to obtain the corresponding values of I_c. The curve i_c, Figure 10, indicates the instantaneous or time (t) values of I_c.

When the potential on grid g_1 is maintained constant, the value of I_k is constant and the effect of placing a varying potential ($e_2 \sin \omega t$) on grid g_2 can be determined as disclosed with reference to Figures 6, 7 and 8, for individual values of I_k. A series of curves can, therefore, be plotted, as in Figure 12*a*, for the constant values of I_k, of C_1, C_2 and C_3, respectively.

A composite group of curves may then be plotted, as in Figures 12*a*, 12*b*, 12*c*, 12*d* and 12*e*, in which the biased instantaneous values of e_{g1} (Figure 12d) may be projected by lines 21 onto Figure 12*c* to obtain instantaneous values of I_k. The biased values of e_{g2} (Figure 12*b*) may be projected by lines 21 onto Figure 12*a*. By selecting the individual curve of Figure 12*a*, corresponding to the instantaneous value of I_k obtained from Figure 12*c*, the instantaneous values of the intermediate frequency current may be plotted as in Figure 12*e*.

It will be apparent that the control grid g_1 and its associated circuit may be combined with the constructions and circuits shown in Figures 2, 3 and 4 by placing grid g_1 in effective control position in relation to cathode 1 in the said figures as is shown in Figure 9. The arrangements thus combined provide other mixing circuits.

There is thus disclosed a method of and apparatus for establishing a field-free region in microwave devices and neutralizing the space charge of the region by trapping the positive ions within the region to concentrate or sweep out the ions to accomplish current modulation amplification or mixing.

I claim as my invention:

1. A reflex-klystron device including a source of electrons, means for providing a focussed beam of electrons therefrom, a resonant cavity, a reflecting electrode, and a plurality of accelerating electrodes that define boundaries of a substantially field-free region in said medium surrounding said cavity each of said accelerating electrodes having an aperture therein the centers of which apertures are in the axis of said beam, and means for controlling the density of said beam comprising means for imposing electric potentials upon said region in the vicinities of the said apertures, whereby the configuration of said field-free region in the vicinities of said apertures are controlled.

2. A reflex-klystron device including a source of electrons, means for providing a focussed beam of electrons therefrom, a resonant cavity, a reflecting electrode, and a plurality of accelerating electrodes that define boundaries of a substantially field-free region in said medium surrounding said cavity each of said accelerating electrodes having an aperture therein the centers of which apertures are in the axis of said beam, and means for variably controlling the density of said beam comprising means for imposing varying electric potentials upon said region in the vicinities of the said apertures, whereby the configuration of said field-free region in the vicinities of said apertures are variably controlled.

3. Apparatus for mixing two currents of different frequency characteristics to obtain a current of an intermediate frequency comprising: means for providing a focussed electron beam in a gaseous medium having a field-free region, means for varying the density of said beam in one region of said medium in accordance with the first of said currents, means for projecting said beam through a second and substantially field-free region of said medium whereby the space charge within the beam is neutralized, a restricted aperture device, means for projecting the said beam through said restricted aperture, means for collecting the electrons of the beam that pass through the said aperture, and means for varying the configuration of the said second region in accordance with the second of said currents, whereby the said beam is concentrated and dispersed as the said beam approaches said aperture and the portion of the electrons in said beam passing through said aperture is varied in accordance with the characteristics of the second of said currents.

4. Apparatus for mixing two currents of different frequency characteristics to obtain a current of an intermediate frequency comprising: means for providing a focussed electron beam in a medium having a field-free region, means for providing an electric field in a first region in the path of said beam, means for varying the said electric field in accordance with the characteristics of the first of said currents, means for projecting the said beam through a second and substantially field-free region of said said medium whereby the space charge within the beam is neutralized, a restricted aperture device, means for passing the said beam through said restricted aperture, means for collecting the electrons of the beam that pass through the said aperture, and means for varying the configurations of the said second region in accordance with the characteristics of the second of said currents whereby the said beam is concentrated and dispersed as the said beam approaches said aperture and the portion of the electrons in said beam passing through said aperture is varied in accordance with the characteristics of the second of said currents.

5. Apparatus for mixing two currents of different frequency characteristics to obtain a current of an intermediate frequency comprising: means for providing a focussed electron beam in a medium having a field-free region, means for varying the density of said beam in one region of said medium in accordance with the frequency characteristics of the first of said currents, means for projecting the said beam through a second and substantially field-free region of said medium, the entering boundary of said second region being a grid and the exit boundary thereof being a restricted aperture, means for impressing position potentials on said boundaries, the grid boundary being biassed positive with respect to said aperture boundary, means for superimposing on said grid a potential varying in accordance with the frequency characteristics of the second of said currents, whereby the said beam is concentrated and dispersed as it approaches said aperture in accordance with the frequency characteristics of the second of said currents, and means for collecting the electrons that pass through said aperture as the current of said intermediate frequency.

6. An electron device including: an electron beam source and a focussed electron beam emitted thereby, a series of electrodes consisting of three apertured electrodes and a solid electrode juxtaposed said beam. the centers of the apertures in said apertured electrodes and the center of said solid electrode being positioned in the axis of the beam, whereby an uninterrupted path for the electrons of said beam is provided from said source to said solid electrode, means for impressing positive electric potentials on said apertured electrodes. whereby a substantially field-free region is established between said apertured electrodes, and means connected to said solid electrode for collecting the electrons in said beam that pass through said apertured electrode.

7. An electron device including: an electron beam source and a focussed electron beam emitted thereby, a series of electrodes consisting of three apertured electrodes and a solid electrode juxtaposed said beam, the centers of the apertures in said apertured electrodes and the center of the said solid electrode being positioned in the axis of the beam, whereby an uninterrupted path for the electrons of said beam is provided from said source to said solid electrode, means for impressing positive electric potentials on said apertured electrodes, whereby a substantially field-free region is established between said apertured electrodes, the potentials on the electrodes nearest the said source and the said solid electrode, respectively, being positive and substantially equal to each other, the potential on the intermediate apertured electrode being positive and of a less potential than the potentials of the other apertured electrodes, and means connected to said solid electrode for collecting the electrons in said beam that pass through said apertured electrode.

8. An electron device including: an electron beam source and a focussed electron beam emitted thereby, a series of electrodes consisting of four apertured electrodes and a solid electrode juxtaposed said beam, the axis of the apertures in said apertured electrodes and the axis of the said solid electrode being positioned in the axis of the beam, whereby an uninterrupted path for the electrons in said beam is provided from said source to said solid electrode, means for impressing positive electric potentials on said apertured electrodes whereby a substantially field-free region is established between said apertured electrodes the potentials on the electrode nearest the said source and the electrode nearest said solid electrode, respectively, being substantially equal to each other, the potential on the two intermediate apertured electrodes being positive and of a less potential than those of the other apertured electrodes, a resonant cavity positioned between the two said intermediate electrodes and means connected to said solid electrode for reflecting the electrons in said beam that pass through said apertured electrodes in a reverse direction into said cavity, whereby electric oscillations are produced in said cavity.

9. An electron device including: an electron focussed beam source and an electron beam emitted thereby, a series of electrodes consisting of three apertured electrodes and a solid electrode juxtaposed said beam, the centers of the apertures in said apertured electrodes and the center of the said solid electrode being positioned in the axis of the beam whereby an uninterrupted path for the electrons of said beam is provided from said source to said solid electrode, means for impressing positive electric potentials on said apertured electrodes whereby electric fields are established between said apertured electrodes, means for supplying a modulating current, means for impressing potentials on said intermediate apertured electrode in accordance with the frequency characteristics of the said modulating current, and means connected to said solid electrode for collecting the electrons in said beam that pass through said apertured electrodes, whereby the said collected electrons constitute a current the frequency characteristics of which correspond to those of the said modulating current.

10. An electron device including: an electron beam source and a focussed electron beam emitted thereby, a series of electrodes constituted of three apertured electrodes and a solid electrode juxtaposed said beam, the centers of the apertures in the said apertured electrodes and the center of the solid electrode being positioned in the axis of said beam and the apertures of the two apertured electrodes nearest the said source being in the form of grids, means for supplying a current of a first frequency, means for supplying a current of a second frequency, means for impressing on the said apertured electrode closest to said source a constant positive potential and superimposed thereon potentials corresponding to said first frequency current, means for impressing on the said apertured electrode next closest to said source a constant positive potential and superimposed thereon potentials corresponding to said second frequency current, means connected to said solid electrode for collecting the electrons of said beam reaching said solid electrode whereby the collected electrons constitute a current of said intermediate frequency, and means for utilizing said collected current.

11. A gaseous medium electron device including a source of electrons, a plurality of accelerating electrodes which define boundaries of a substantially field-free region in said medium, said electrodes having coaxial apertures therein, means for focusing electrons from said source into a beam coaxial with said apertures, means for accelerating said beam to pass through said electrode apertures, means for applying potentials to said boundaries of said region to establish said field-free region thereby creating ions in said

region by collisions of said electrons with the molecules of said medium and hence trapping said ions within said beam within said region to neutralize the space charge in said beam in said region, and means for imposing an electric potential upon the boundaries of said region in the vicinity of the said aperture closest to said source for controlling the density of said electron beam passing through said region.

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