

Sept. 8, 1964

P. A. CLAVIER ET AL

3,148,302

MICROWAVE AMPLIFIER TUBE WITH DIRECT CURRENT FIELD
INTERACTION MEANS FOR THE ELECTRON BEAM

Filed Sept. 9, 1959

7 Sheets-Sheet 1

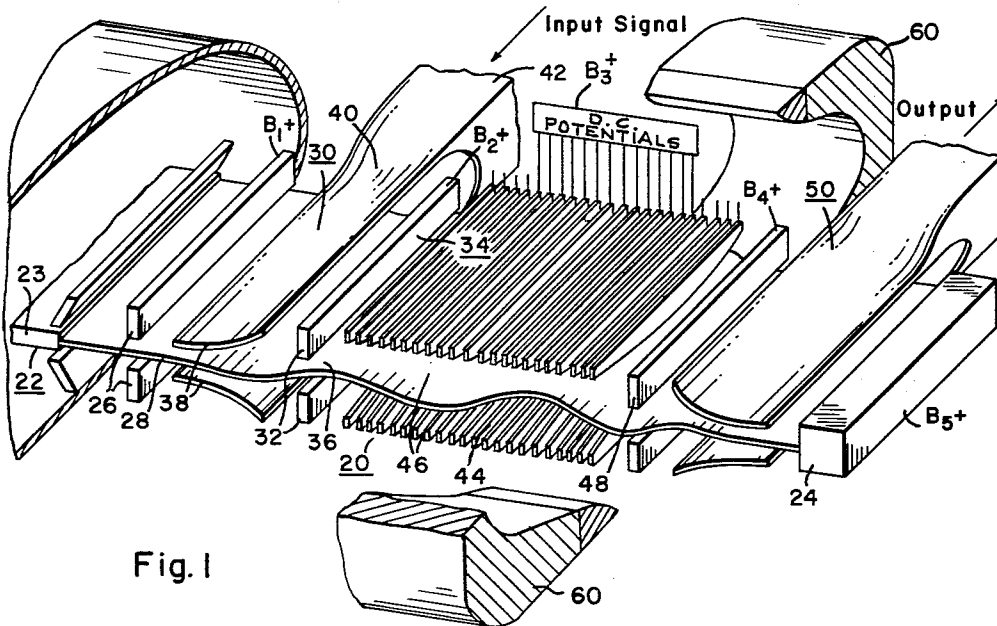


Fig. 1

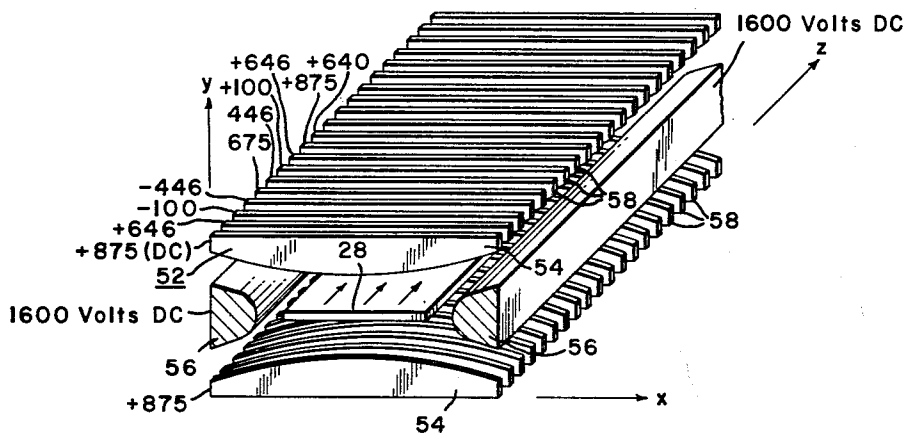


Fig. 2

WITNESSES

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7 Sheets-Sheet 2

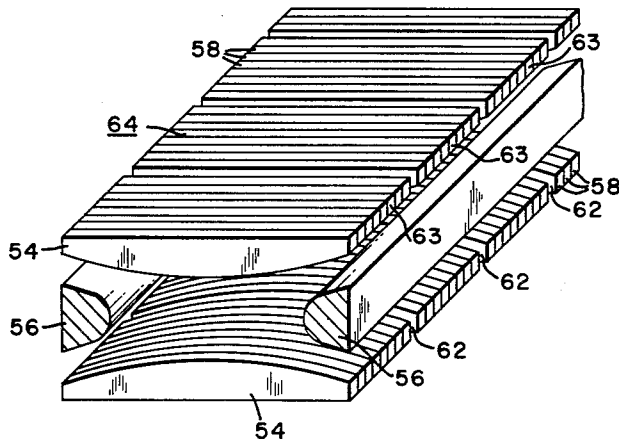


Fig. 3

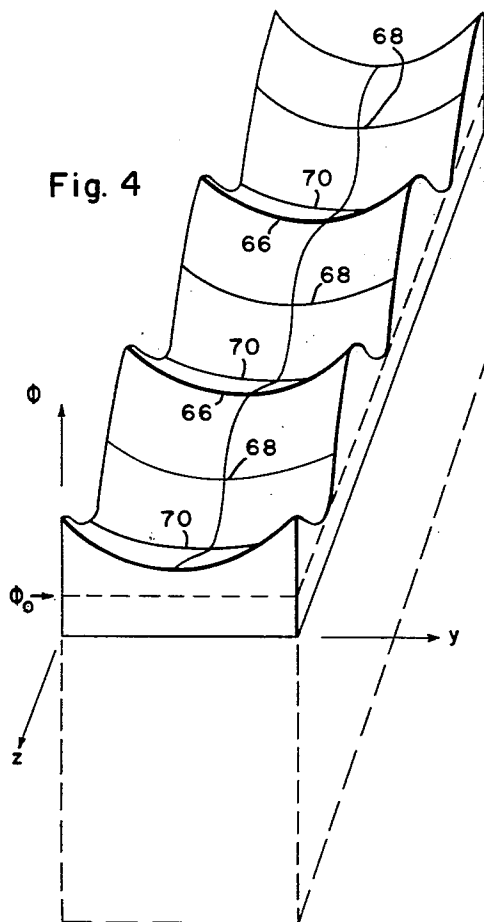


Fig. 4

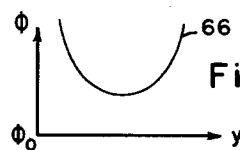


Fig. 5a

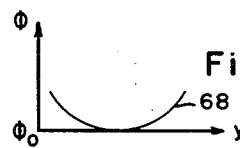


Fig. 5b

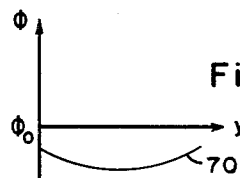


Fig. 5c

Sept. 8, 1964

P. A. CLAVIER ET AL

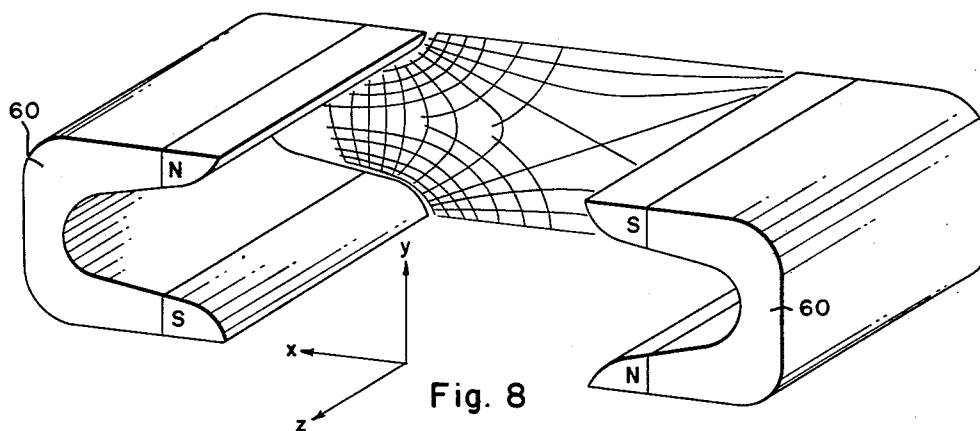
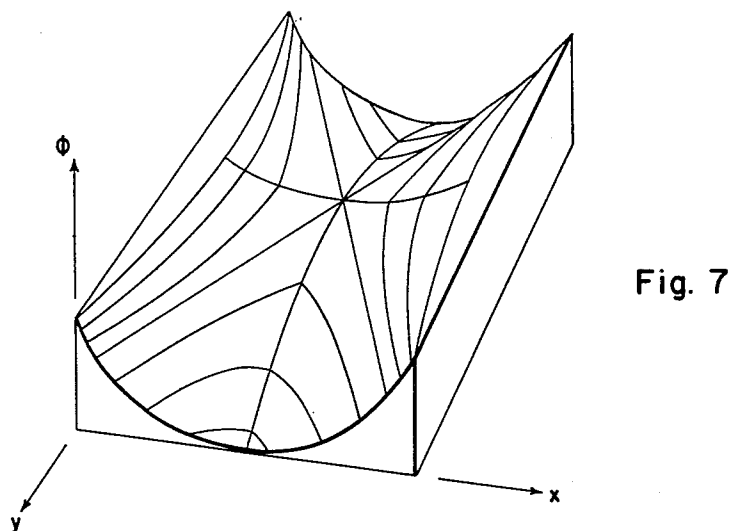
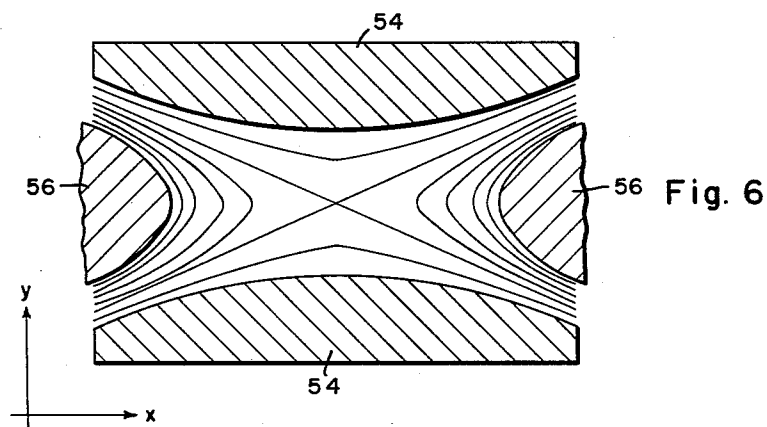
3,148,302

MICROWAVE AMPLIFIER TUBE WITH DIRECT CURRENT FIELD

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Filed Sept. 9, 1959

7 Sheets-Sheet 3



Sept. 8, 1964

P. A. CLAVIER ET AL
MICROWAVE AMPLIFIER TUBE WITH DIRECT CURRENT FIELD
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3,148,302

Filed Sept. 9, 1959

7 Sheets-Sheet 4

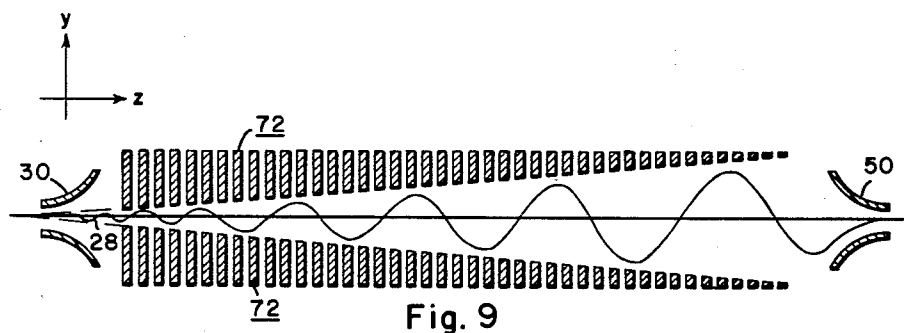


Fig. 9

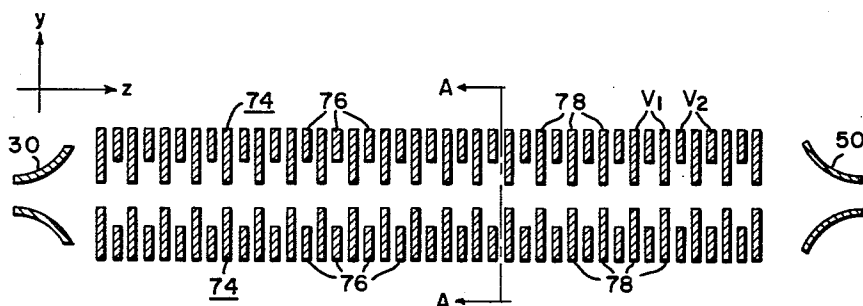


Fig. 10

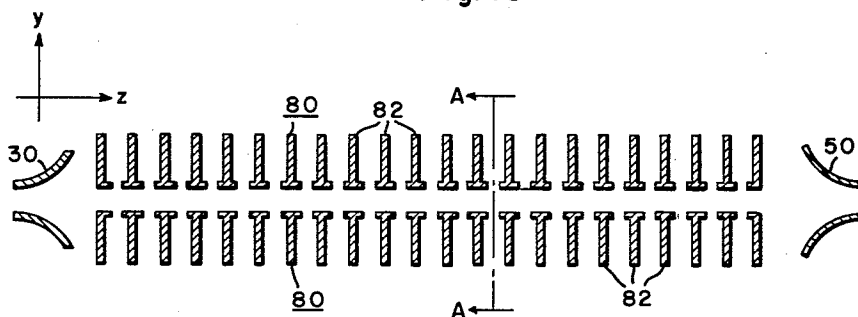


Fig. 11

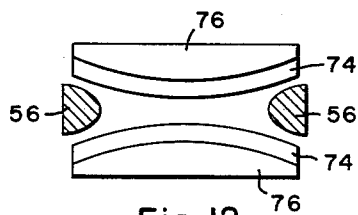


Fig. 12

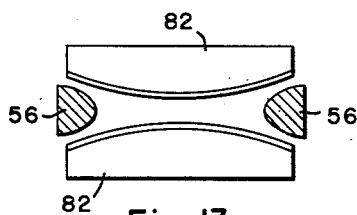


Fig. 13

Sept. 8, 1964

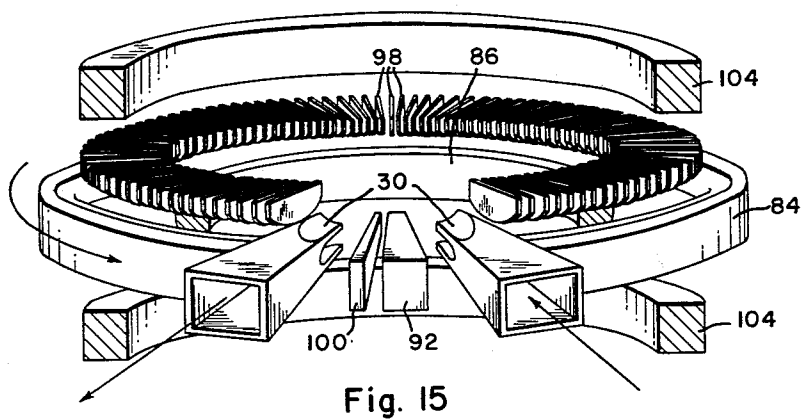
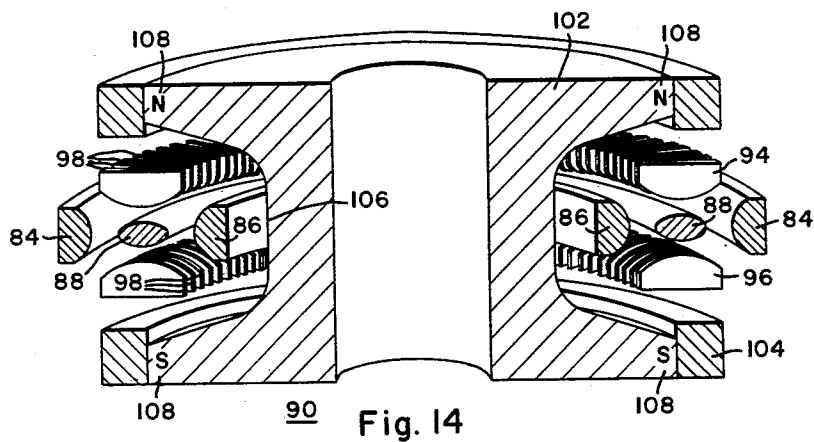
P. A. CLAVIER ET AL

3,148,302

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Filed Sept. 9, 1959

7 Sheets-Sheet 5



Sept. 8, 1964

P. A. CLAVIER ET AL

3,148,302

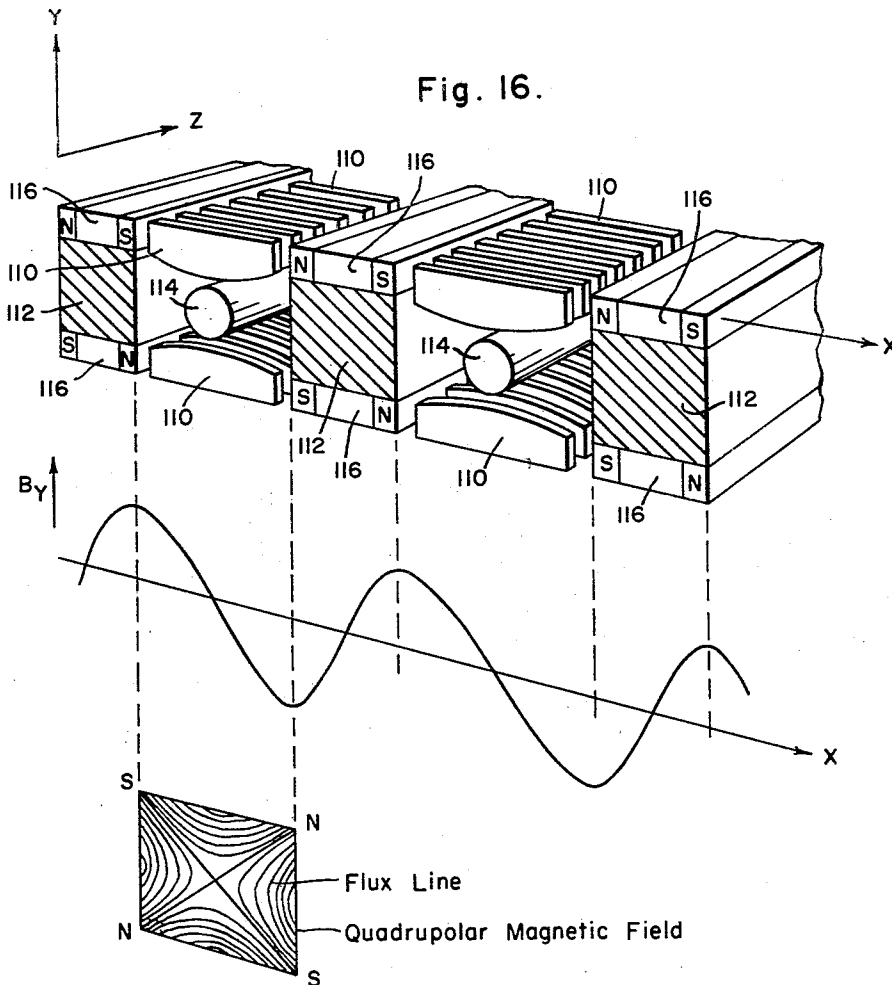
MICROWAVE AMPLIFIER TUBE WITH DIRECT CURRENT FIELD

INTERACTION MEANS FOR THE ELECTRON BEAM

Filed Sept. 9, 1959

7 Sheets-Sheet 6

Fig. 16.



Sept. 8, 1964

P. A. CLAVIER ET AL

3,148,302

MICROWAVE AMPLIFIER TUBE WITH DIRECT CURRENT FIELD

INTERACTION MEANS FOR THE ELECTRON BEAM

Filed Sept. 9, 1959

7 Sheets-Sheet 7

Fig. 17.

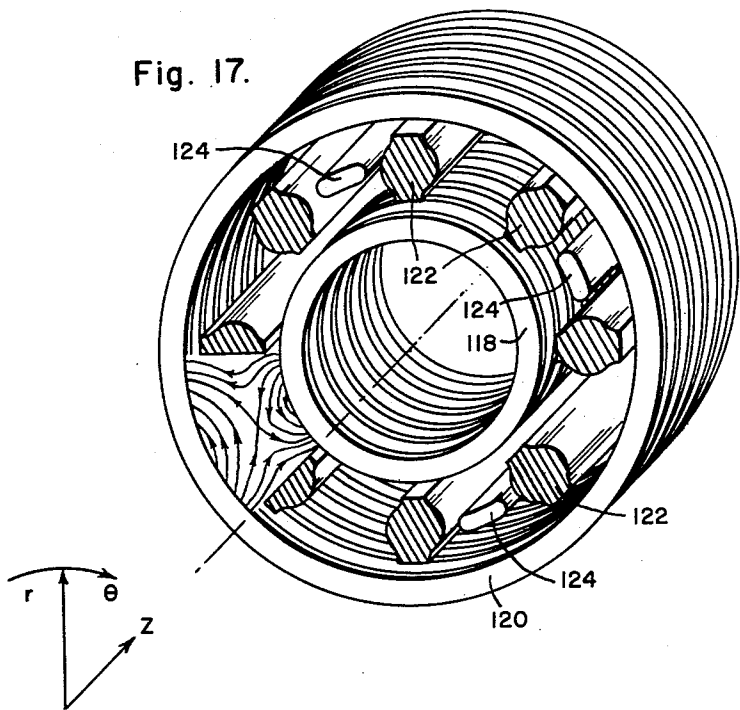
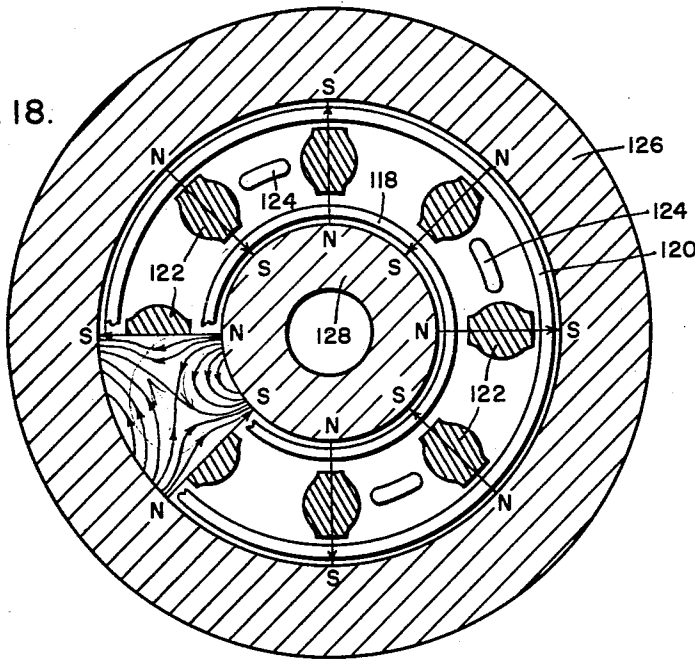


Fig. 18.



1

3,148,302

MICROWAVE AMPLIFIER TUBE WITH DIRECT CURRENT FIELD INTERACTION MEANS FOR THE ELECTRON BEAM

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12 Claims. (Cl. 315-3)

This invention relates to electron discharge devices and more particularly to a microwave amplifier.

Present microwave amplifiers can be divided into two main classes. One class includes tubes such as klystrons, traveling wave tubes and some crossed field devices. These tubes achieve amplification by converting energy from a D.C. power source into RF signal energy. In the second class, which includes the parametric amplifier, amplification is achieved by converting energy from an A.C. power source or pump into RF signal energy. Each of these classes of microwave amplifiers has certain limitations; for example, the tubes in the first class are limited in either efficiency, gain or bandwidth, and these tubes have the additional disadvantage that very small dimensions are required at high frequencies of operation. The amplifiers in the second class are relatively new and their performance characteristics have not been fully explored, but they are known to have the disadvantage of small dimensions at high frequencies and a highly distorted output frequency spectrum. Also, they require a pump generator which must operate at a higher frequency than that of the signal being amplified. This obviously presents a very serious limitation for high frequency operation.

It is therefore an object of this invention to provide an improved amplifier which possesses all the advantages of the amplifiers in the two classes mentioned before but which does not have the limitations of these amplifiers.

It is another object of this invention to provide a microwave amplifier which converts D.C. power into RF signal energy at a very high efficiency.

It is a further object of this invention to provide a microwave amplifier which utilizes transverse modulation of an electron beam and D.C. pumping to obtain amplification of the input RF signal.

It is an additional object of this invention to provide a microwave amplifier in which the amplifying interaction process is independent of the signal frequency.

It is an auxiliary object of this invention to provide a microwave amplifier from which a high gain may be obtained without distorting the input signal.

It is a supplementary object of this invention to provide a microwave amplifier having means to provide the proper average electron beam velocity in relation to the potential distribution at the location of the electron beam to obtain amplification of an input signal.

These and other objects of this invention will be apparent from the following detailed description taken in accordance with the accompanying drawings, throughout which like reference characters indicate like parts which drawings form a part of this application, and in which:

FIGURE 1 is a schematic presentation partially in section and partially broken away of the overall structure of the amplifier of this invention showing the coupling arrangement;

FIG. 2 shows a schematic presentation of an electrode structure for the amplifier interaction region.

FIG. 3 shows a perspective schematic view of an alternate electrode arrangement for the interaction region.

FIG. 4 shows a three dimensional plot of a D.C. poten-

2

tial distribution suitable for stable operation of the amplifier.

FIG. 5 shows three plots which indicate the distribution and level of D.C. potential at points 66, 68 and 70 respectively in FIG. 4.

FIG. 6 is a cross sectional view of the electrode structure of FIG. 2 showing the potential distribution.

FIG. 7 shows a three dimensional schematic view of the potential distribution at the mid-plane of a section of the amplifier structure.

FIG. 8 shows the potential distribution of an elongated magnetostatic quadrupole.

FIG. 9 shows a longitudinal section view of an alternate embodiment of the upper and lower electrodes of the interaction region.

FIG. 10 shows a longitudinal section view of an alternate embodiment of the upper and lower electrodes in which only one potential is used on these electrodes.

FIG. 11 shows a longitudinal section view of an embodiment in which the upper and lower electrodes comprise one segment per period of interaction structure.

FIG. 12 shows a transverse sectional view of the electrode structure taken along line A—A of the structure shown in FIG. 10.

FIG. 13 shows a transverse section view of the electrode structure shown in FIG. 11 taken along line A—A.

FIG. 14 shows a section view of a circular amplifier in accordance with the present invention.

FIG. 15 shows a view of the circular amplifier with part of the magnetic structure cut away to show details of the electrode structure.

FIG. 16 shows a linear arrangement of a multi-beam amplifier.

FIG. 17 shows a circularly arranged multi-beam amplifier.

FIG. 18 shows a sectional view of the tube shown in FIG. 17 with the magnetic structure in place.

The drawings are marked with an X, Y, Z coordinate system in which Y is the direction of transverse interaction, Z is the direction of flow of the electron beam, and X is the direction perpendicular to both the direction of transverse interaction and the direction of flow of the electron beam.

In its broader aspects this invention describes a new type of amplifier which is capable of linear, efficient, broad band amplification at microwave frequencies and is particularly suited for ultra short wavelengths since the amplification process is totally independent of the signal frequency. Although many of its important properties are different, it may be thought of as a parametric amplifier type device with a D.C. pump. In the present invention, amplification is obtained by the interaction of an electron beam with a periodic electrostatic field. The electrons in the beam see the periodic electrostatic field as if it were the field of the time varying pump of a conventional parametric amplifier.

Referring now to FIG. 1 of the drawing there is shown a microwave amplifier tube constructed in accordance with the invention. The tube 20 comprises an evacuable envelope 10 having at one end an electron gun 22 and at the other end a collector electrode 24. The cathode 23 of the electron gun has an emission surface which is coated with an electron-emissive substance, and the cathode 23 is heated to emission temperature by any suitable means, such as a heater (not shown). A cloud of electrons is thermionically emitted from the emission surface of the cathode 23 and fills the region immediately adjacent thereto. An anode 26, provided adjacent cathode 23, is maintained at an adjustable positive potential and action of the electric field established by the anode 26 draws and focuses the emitted electrons through an aper-

ture within the anode 26 and thereby forms a high per-
 veance beam of electrons 28.

An electron beam of any suitable cross section, such
 as a solid cylindrical beam for example, could be used
 in this amplifier. It is advantageous to use a sheet beam
 as shown in the drawings since a sheet beam provides a
 larger beam area to interact with the RF fields in the
 couplers and also has a higher power handling ability.
 The formed and focused electron beam 28 is then ac-
 celerated toward an input coupler 30 substantially along
 the longitudinal axis of the tube 20.

An input RF signal is introduced through the input
 coupler 30, and this input signal is impressed upon the
 electron beam as it passes through the input coupler 30
 so as to modulate the beam position according to the
 input signal.

The input coupler 30 may be any suitable type of
 transverse coupler. In the embodiment shown in the
 drawings, in which the width of the sheet beam is per-
 pendicular to the transverse direction of the interaction
 in the amplifier, it is practical to use as couplers wave-
 guides which propagate along the width of the beam.
 Each of the couplers shown comprises two structures 38
 symmetrically disposed around the central plane of the
 tube and separated by an opening to permit passage of
 the electron beam 28. The geometry of the coupler 30
 must be the same all along the region where the beam
 passes through the coupler so that the action on the
 electron beam will be the same in all cross sections. Out-
 side the beam region, the coupler may be continued by
 a transition 40 to the usual type of commercially avail-
 able waveguide 42.

The electron beam 28 then passes through a coupler
 exit lens system 34 which serves to further collimate the
 beam 28. The lens system illustrated in the drawings
 comprises members 32 to which suitable potentials are
 applied and having an aperture 36 through which the
 electron beam 28 passes. In many cases the input beam
 conditions necessary for the interaction region do not
 match exactly the boundary conditions necessary for
 proper operation of the coupler. The coupler exit lens
 34 may also be designed to achieve the desired boundary
 conditions between the coupler and the interaction region.

The beam 28 then passes through the interaction re-
 gion 44 where it is acted on by the applied electrostatic
 potentials to amplify the signal imposed upon the electron
 beam in the input coupler 30. The energy of the electron
 beam entering the interaction region may be about 1500
 volts. The interaction region 44 comprises in general
 segmented spaced electrodes 46 to which a suitable poten-
 tial or potentials are applied to obtain the proper action
 on the electron beam to insure amplification of the beam
 as it passes through the interaction region 44. A de-
 tailed description of the electrode structure in the in-
 teraction region 44 will be included below with respect to
 FIG. 2.

As the amplified electron beam 28 leaves the interaction
 region 44 a coupler input lens system 48 acts to orient
 the beam as it enters the output coupler 50. The coupler
 input lens 48 is similar in structure to the coupler output
 lens 34, and may also be used to match the boundary
 conditions between the interaction region 44 and the out-
 put coupler 50. The output coupler 50 develops an out-
 put signal in response to the transverse modulation im-
 posed upon the electron beam 28 in the input coupler 30
 and amplified through the interaction region 44. This
 output signal is transmitted to an external utilization cir-
 cuit. The output coupler 50 is similar in structure to the
 input coupler 30. The electron beam 28 is terminated
 upon the collector electrode 24 which is maintained at
 a positive potential with respect to the cathode 23.

The electrode structure 46 shown in FIG. 1 within the
 interaction region 44 may be that shown in FIG. 2. This
 electrode structure 52 comprises upper and lower elec-
 trodes 54 and right and left electrodes 56. The upper

and lower electrodes 54 are comprised of an array of
 insulated segments 58 to which suitable D.C. potentials
 are applied such as indicated in FIG. 2. The voltages
 have been indicated for one period and repeat down the
 structure. The right and left electrodes 56 do not have
 to be segmented. The right and left electrodes 56 are
 both operated at a positive D.C. potential of about 1600
 volts which is higher than the average potential in the
 interaction region 44. The D.C. potential applied to the
 insulated segments 58 of the upper and lower electrodes
 54 varies from segment to segment in the direction (Z)
 of flow of the electron beam 28. Segments 58 of the
 upper and lower electrodes 54 which are in the same cross
 section are operated at the same potential. The electrode
 structure 52 and associated voltages provide a quadru-
 polar electrostatic field as illustrated in FIG. 6.

In certain cases, it may be necessary to provide addi-
 tional focusing means for the electron beam 28 in the
 direction (X) substantially normal to the direction (Y)
 of its deflection in the interaction region 44. The addi-
 tional focusing can be provided by a magnetic field in the
 direction (Y). The strength of which varies linearly in
 the direction (X) and the value of which is zero at the
 center of symmetry of the tube. One way of generating
 such a magnetic field is by means of the structure shown
 in FIG. 8, for example. This magnetic structure com-
 prises essentially two horse shoe magnets 60 arranged
 equidistant from the tube axis and with opposing poles
 so that the resultant magnetic field at the axis of the tube
 is essentially zero. This structure provides a quadrupolar
 magnetic field. The required magnetic field can also be
 provided by passing D.C. currents of suitable strength in
 the right and left hand electrodes 56. This current must
 flow in the direction of motion of the electrons in the
 beam. Often, however, the current necessary to produce
 such a field is excessive.

If more focusing in the direction of the displacement
 of the electron beam is required, this focusing can be
 obtained by producing a periodic electrostatic focusing
 lens system by changing the average potential applied to
 the upper and lower electrodes 54 in a suitable manner.
 This change would have a large period compared to the
 period of the array of potentials applied to the upper
 and lower electrodes 54 for purposes of interaction. One
 way of accomplishing this result is to divide the struc-
 ture shown in FIG. 2 into a series of units 63 separated
 by a gap 62 such as the structure 64 shown in FIG. 3.
 Each of these units is composed of a large number of
 periods of interaction potential. Each unit has impressed
 on it a suitable average potential which is varied from
 unit to unit down the structure. Because the average
 potential is changed from unit to unit, either the spac-
 ing between the segments which make up the upper and
 lower electrodes must be varied from unit to unit or
 the potential distribution on these segments 58 must be
 modified from unit to unit so as not to disturb the
 parametric interaction.

One of the features of this invention which distin-
 guishes it from the parametric amplifiers is that it
 achieves an analogous pumping action without requiring
 an A.C. pump. To achieve a similar result in the pres-
 ent invention, the interaction structure of the electronic
 parametric amplifier is replaced by a periodic array of
 electrodes through which the electron beam travels.
 D.C. voltages are impressed on the electrodes in such
 a way as to provide the required potential distribution.
 In the parametric amplifier, the electron, while moving
 from input to output, experiences a periodically time
 varying restoring force generated by the A.C. pump.
 The effect on the electron would be the same if the re-
 storing force would not vary in time, but vary periodically
 along the electron path in such a way that the restor-
 ing force seen by the electron at a given time would
 be the same in both cases. A three dimensional sche-
 matic presentation of the type of potential distribution

that must be provided along the interaction region 44 to achieve this result is shown in FIGS. 4 and 5. This distribution must provide transverse potential wells 66, 68, 70, the steepness of the sides of which must vary periodically along the path of the beam as shown in FIG. 5. In order to satisfy Laplace's equation, such a transverse distribution of potential is not possible without a corresponding variation of potential along the direction of flow of the beam. A three dimensional schematic presentation of the type of potential distribution that may be used to achieve this result is shown in FIG. 4. The variation of potential in the direction of the beam, however, can be kept small compared with the average potential of the bottoms of the wells. It is important that the curvature of the potential wells does not change sign since otherwise conditions for amplification would require potentials lower than cathode potential in the path of the electrons and a beam could not be formed. It is therefore very important that a periodic array of potential wells which will always provide a position of stable equilibrium for operation of the beam be provided. The potential distribution shown in FIG. 4 is thus obtained by superimposing a small periodic variation on the potential shown on FIG. 6 and FIG. 7. FIG. 6 is a plot of the equipotential lines of the average potential distribution on any cross-section orthogonal to the direction of flow of the beam. FIG. 7 is an elevation of the same plot.

By means of the potential distribution, the desired restoring forces are obtained in the direction (Y) of the beam modulation orthogonal to the direction (Z) of flow of the beam. However, from Laplace's equation there are also diverting forces in the direction (X) normal to the flow of the beam direction (Z) and to the direction (Y) of the beam modulation. To prevent spreading of the beam in the direction (X) normal to the direction (Y) of beam modulation, these diverting forces must be neutralized by equal and opposite forces. These neutralizing forces can be provided by a magnetic field in the direction (Y) of beam modulation, the strength of which varies linearly with the displacement perpendicular to the direction (Y) of beam modulation and to the direction (Z) of flow of the electron beam and the value of which is zero at the center of the system. One way of generating such a magnetic field is by means of a magnetic quadrupole as shown in FIG. 8. This magnetic quadrupole field pattern is elongated in the direction (X) perpendicular to the direction (Y) of beam modulation and to the direction (Z) of flow of the electron beam so as to provide a strong magnetic field in the direction (Y) of beam modulation while minimizing the field in the direction perpendicular to the direction (Y) of beam modulation and to the direction (Z) of flow of the electron beam. By using a sufficiently strong magnetic field it is possible to overcompensate the diverting forces and also prevent space charge spreading of the beam in the direction (X) perpendicular to the direction (Y) of beam modulation and to the direction (Z) of flow of the electron beam.

To obtain the proper potential distribution the upper and lower electrodes 54 of the quadrupole as shown in FIG. 2 consist of an array of thin insulated segments 58 to which a periodic potential distribution can be applied. The left and right hand electrodes 56 of FIG. 2 however can be equi-potential surfaces and do not need to be segmented.

Because the interaction occurs only in one certain direction it is desirable but not essential to use a sheet electron beam in a structure such as the present invention. A sheet electron beam permits the tube to handle more power.

In the present invention, the input and output couplers may be any ordinary type of transverse couplers. In the input coupler the beam acquires a transverse velocity and subsequently a transverse displacement. At

the start of the interaction space a transverse velocity and a transverse displacement behave differently. By starting the potential distribution in the interaction space by a potential well whose cross section is of average steepness, it is possible to enhance the transverse oscillations generated by the transverse velocity and damp the oscillations generated by transverse displacement. This situation is advantageous for two reasons: first, because a short coupler imparts principally a transverse velocity modulation rather than a transverse displacement and second, because a well collimated D.C. beam can have a certain thickness but very little inherent transverse velocity spread. While electrons entering the interaction space 44 with a D.C. transverse velocity will oscillate as if they had acquired this transverse velocity in the coupler, electrons entering at a certain distance from the central plane will experience damped oscillations and tend toward the central plane. Thus a certain amount of focusing is obtained automatically.

Because the apparent phase of the pump as seen by the beam when it enters the interaction space 44 is fixed by the electrostatic potential distribution at the entrance, any oscillations generated by transverse velocities are equally amplified independently of the time of entrance. Because of this, the amplification in the present device is inherently linear. As in parametric amplifiers, the amplification process in the present device is completely independent of the input signal spectrum. However, because this is a linear device, there is none of the spectral distortion in the output of the device of the present invention which occurs in the parametric amplifier.

In the present device all electrons in the same cross section of the beam are acted upon in the same manner. The D.C. energy in the direction of flow provided to the electron beam is principally a means to carry the electrons from input to output. This energy can be diminished by usual sunken collector techniques. The only peculiar lossy effect is the collimation of the electrons which are emitted with over-large transverse velocities at the cathode. These electrons may be eliminated in a low potential region in the gun. Since no internal attenuator and no delicate waveguiding structure is required within the interaction region, the device of the present invention has excellent high power capabilities. In this device, a large percentage of the A.C. power can be transferred to the beam and extracted from the beam, for example, at 10,000 megacycles using a particular design it is theoretically possible to extract 99.7% of the A.C. energy with a coupler two centimeters long.

In certain cases in which it is advantageous to obtain large transverse amplitudes of the oscillations of the electron beam, it is necessary to keep the upper and lower electrodes far from the beam. On the other hand, to shape the potential distribution near the entrance to the interaction region properly, the electrodes should be kept close to the beam. It is advantageous in this case to progressively increase the distance between the upper and lower electrodes 72 along the direction of beam flow as shown in FIG. 9. In order to keep the proper potential distribution in the region of the beam, the increase in distance between electrodes 72 must be compensated for by a suitable increase in electrode voltage.

Since two sets of electrodes are provided, it is possible to obtain the transverse variations of potential by applying only two voltages to the interaction structure, namely a high potential on both the right and left hand electrodes and the lower potential on both upper and lower electrodes 74. To accomplish this result it is necessary to vary periodically the gap width between the upper and lower electrodes as shown in FIG. 10 by providing alternate small segments 76 and large segments 78 which comprise the upper and lower electrodes 74.

Transverse potential wells exist even in the cross section between segments of the upper and lower electrodes 80. In certain cases, it is possible to obtain the neces-

sary distribution of potential along the interaction region using only one segment 82 for each period of the electrode structure. This arrangement is shown in FIG. 11.

A number of cylindrical electron beams arranged in a linear array may be used such as the arrangement shown in FIG. 16. In this case, upper and lower electrodes 110 are similar to the segmented electrodes described previously. The right and left hand electrodes previously described are replaced by a series of similarly functioning electrodes 112 inserted between the electron beams 114. The strength of the magnetic field in the direction of interaction must now vary periodically in the direction perpendicular to both the direction of interaction and to the direction of flow of the electron beam, with a period equal to the distance between axes of adjacent beams, and in such a manner that it changes sign at the axis of each beam. Such a field can be generated by two rows of magnets 116 of alternate polarity as shown in FIG. 16.

Because the number of beams is finite, the strength of the pole pieces, if they are equally spaced, must increase from the center toward the edge of the structure in order to provide a truly periodic magnetic field. Alternately, equal strength pole pieces which are spaced at unequal intervals may be used.

It is also possible to obtain the magnetic field by passing D.C. currents in the electrodes between the beams. While all of the currents flow in the direction of motion of the electrons in the beams, the magnitude of the currents must increase somewhat from the center to the edge of the structure.

The present principle of operation can also be used in a tube which has a number of cylindrical electron beams arranged in a circular array such as that shown in FIG. 17. In this case the upper and lower electrodes of the original structure become the inner electrode 118 and the outer segmented electrode 120. The right and left hand electrodes of the original structure are replaced by a series of similarly functioning electrodes 122 inserted between the electron beams 124. The magnetic field strength in the radial direction must be a periodic function of the azimuth angle with a period equal to 2π divided by the number of beams. The field must change sign on the axis of each beam. Such a field pattern can be produced by two coaxial rings of poles as shown in FIG. 18. In this case the pole strengths of all poles of the outer multipolar permanent magnet 126 and also of all poles of the inner multipolar permanent magnet 128 are equal, but the inner and outer pole strengths are different. In this case also the magnetic field can be provided by D.C. current flow in the electrodes between the beams. The currents in the electrodes are all equal and flow in the direction of motion of the beams.

A circular amplifier 90 in accordance with the present invention is shown in FIGS. 14 and 15. This tube operates substantially as described in detail earlier in this specification but is arranged in a circular fashion. Some changes are necessary to utilize the circular shape. It is necessary to provide a constant magnetic field in the direction of interaction in addition to the previously discussed magnetic field which prevents the beam from spreading. This additional magnetic field is necessary to maintain the electron beam in its circular orbit. In the embodiment shown in the drawings, the required composite magnetic field is supplied by an annular magnetic member 102 having a recess portion within which the electrode structure of the interaction region is positioned. The magnetic member 102 is surrounded at its top and bottom pole members 108 by a pole piece ring 104. Also, it may be desirable to add a radial electric field between the right hand electrode 86 and left hand electrode 84. An annular electron beam 88 is used in this tube 90 instead of the sheet beam used in the rectilinear embodiment. The upper electrode 94 and the lower electrode

96 are divided into insulated segments 98 as in the rectilinear embodiment. The same type input and output couplers 30 are used in both the circular and rectilinear embodiments. A possible feature of this annular beam amplifier is to use all or a portion of the returning beam to heat, by bombardment, the cathode of the electron gun 92 which is located adjacent to the collector 100. By this feature the cathode heater power could be reduced or eliminated once the device is started.

While the present invention has been shown in only a few forms it will be obvious to those skilled in the art that it is not so limited but is susceptible of various changes and modifications without departing from the spirit and scope thereof.

We claim as our invention:

1. A microwave amplifier comprising means for producing an electron beam, signal input coupling means, signal output coupling means, spaced electrodes forming an interaction region between said input and output signal coupling means, means for impressing a direct current voltage on said spaced electrodes to establish a direct current field in said interaction region which varies along the path of said electron beam such that an electron passing through said interaction region is influenced in a manner similar to a time varying pumping field, and field producing means for preventing the spread of said electron beam in a predetermined direction perpendicular to the direction of flow of said electron beam, said signal input coupling means responsive to an input signal to produce deflections of said electron beam in a direction perpendicular to both said predetermined direction and the direction of flow of said electron beam, said interaction region adapted to increase said deflection of said electron beam as said electron beam traverses said interaction region, and said output coupling means responsive to said deflections in said electron beam to produce an output signal that is an amplified signal representative of said input signal.

2. A microwave amplifier comprising electron gun means for projecting an electron beam along a given path, a signal input coupling means, means defining an interaction region, and a signal output coupling means spaced along said given path, means to provide an array of transverse electrostatic direct current potential wells such that the steepness of the sides of the wells varies along the array, said signal input coupling means comprising a transverse input coupler which impresses a transverse linear modulation on said electron beam in response to a transverse input signal, and magnetic means for preventing the spread of said electron beam in the direction perpendicular to the direction of said transverse modulation, said electrostatic potential wells adapted to increase the transverse motion of said electron beam as it passes through said interaction region, said output signal coupling means comprising a transverse coupler designed to extract the amplified transverse modulation from said electron beam and produce an output signal that is an amplified signal representative of said input signal.

3. A microwave amplifier comprising an evacuated envelope having an axis, means for projecting an electron beam having a rectangular cross section along said axis, a signal input coupler, means defining an interaction region and a signal output coupler spaced along said axis, said interaction region defining means including an upper electrode, a lower electrode, a right electrode and a left electrode, said right and left electrodes comprising continuous elongated conductive members, said upper and lower electrodes comprising a plurality of insulated segments, magnetic means for preventing the spread of said electron beam in a direction normal to said axis and parallel to the plane of the electron beam, said signal input coupler responsive to an input signal to produce a deflection of said electron beam from said axis toward the upper or lower electrode depending on the

phase of the input signal, and means for applying an electrostatic direct current potential to each of said segments of said upper and lower electrodes, said electrostatic potential varying from segment to segment of said upper and lower electrodes so as to increase the transverse deflection of said electron beam as it progresses along said interaction region, said output signal coupler responsive to the deflection of said electron beam from said axis to produce an output signal representative of an amplified input signal.

4. A microwave amplifier comprising means for projecting an electron beam along an axis, a signal input coupler, means defining an interaction region and signal output coupler spaced along said axis, said interaction region defining means including an upper electrode, a lower electrode, a right electrode and a left electrode, magnetic means for preventing the spread of said electron beam in a predetermined direction orthogonal to the direction of flow of said electron beam, said signal input coupler responsive to an input signal to produce a transverse modulation on said electron beam, and means for applying an electrostatic direct current potential to said upper and lower electrodes and said right and left electrodes bounding said interaction region to provide a spatially varying multipolar electrostatic field to increase the transverse excursion of said electron beam as said electron beam passes through said interaction region, said output signal coupler responsive to said transverse modulation of said electron beam to produce an output signal representative of an amplified input signal.

5. A microwave amplifier comprising means for producing an electron beam, signal input coupling means, signal output coupling means, and means between said input and output signal coupling means including an upper electrode, a lower electrode, a right electrode and a left electrode defining an interaction region, said upper and lower electrodes comprising an array of insulated segments, said right and left electrodes comprising a continuous elongated conductive member, magnetic means for preventing the spread of said electron beam in a predetermined direction orthogonal to the direction of flow of said electron beam, said input coupler responsive to an input signal to produce a transverse modulation on said electron beam, and means for applying a direct current potential to said segments of said upper and lower electrodes bounding said interaction region, said direct current potential varying from segment to segment along said interaction region to increase the transverse excursion of said electron beam as said electron beam passes through said interaction region, said output signal coupler responsive to said transverse modulation of said electron beam to produce an output signal representative of an amplified input signal.

6. A microwave amplifier comprising means for projecting an electron beam along an axis, a signal input coupler, electrode means defining an interaction region and a signal output coupler spaced along said axis, said interaction region defined by an upper electrode, a lower electrode, a right electrode and a left electrode, said upper and lower electrodes comprising an array of insulated segments, said segments of said upper and lower electrodes divided into a plurality of sections, said sections each separated by a gap, magnetic means for preventing the spread of said electron beam in a predetermined direction orthogonal to the direction of flow of said electron beam, said signal input coupling means responsive to an input signal to produce deflections of said electron beam in a direction orthogonal to both said predetermined direction and the direction of flow of said electron beam, means for applying an electrostatic direct current potential to said upper and lower electrodes bounding said interaction region, said electrostatic potential varying from section to section of said upper and lower electrodes for focusing said electron beam, said output signal coupler responsive to said transverse modulation of said electron

beam to produce an output signal representative of an amplified input signal.

7. A microwave amplifier comprising means for projecting an electron beam along an axis, a signal input coupling means, spaced electrodes forming an interaction region and a signal output coupler spaced along said axis, said spaced electrodes forming said interaction region comprising an upper electrode, a lower electrode, a right electrode and a left electrode, said upper and lower electrodes comprising an array of insulated segments, said segments of said upper and lower electrodes spaced a progressively greater distance from said axis as said interaction region is traversed from said signal input coupler to said signal output coupler, said right and left electrodes comprising continuous elongated conductive members, means for impressing an electrostatic direct current potential to each of said segments of said upper and lower electrodes to establish a direct current field in said interaction region which varies along the path of said electron beam such that an electron passing through said interaction region is influenced in a manner similar to a time varying pumping field, and field producing means for preventing the spread of said electron beam in a predetermined direction orthogonal to the direction of flow of said electron beam, said signal input coupling means responsive to an input signal to produce deflections of said electron beam in a direction orthogonal to both the predetermined direction and the direction of flow of said electron beam, said interaction region adapted to increase said deflection of said electron beam as said electron beam traverses said interaction region and said output coupler responsive to said deflections of said electron beam to produce an output signal that is an amplified signal representative of said input signal.

8. A microwave amplifier comprising means for projecting an electron beam along an axis, a signal input coupler, means defining an interaction region and a signal output coupler spaced along said axis, said interaction region defining means comprising an upper electrode, a lower electrode, a right electrode and a left electrode, said upper and lower electrodes comprising an array of insulated segments, alternate segments of said upper and lower electrodes spaced a first distance from said axis and the remainder of said segments spaced a second distance from said axis along said interaction region, means for applying a first direct current potential to each of said segments spaced a first distance from said axis and a second direct current potential to the remainder of said segments of said upper and lower electrodes to establish a direct current field in said interaction region which varies along the path of said electron beam such that an electron passing through said interaction region is influenced in a manner similar to a time varying pumping field, said right and left electrodes comprising continuous elongated conductive members, field producing means for preventing the spread of said electron beam in a predetermined direction orthogonal to the direction of flow of said electron beam, said signal input coupler responsive to an input signal to produce deflections of said electron beam in a direction orthogonal to both said predetermined direction and the direction of flow of said electron beam, said interaction region adapted to increase said deflection of said electron beam as said beam traverses said interaction region and said output signal coupler responsive to said transverse modulation of said electron beam to produce an output signal representative of an amplified input signal.

9. A microwave amplifier comprising means for producing an electron beam, signal input coupling means, signal output coupling means and spaced electrodes forming an interaction region between said input and said output signal coupling means, said spaced electrodes and said interaction region arranged in a circular fashion, means for applying an electrostatic direct current potential to said spaced electrodes to establish a direct current

11

field in said interaction region which varies along the path of said electron beam such that an electron passing through said interaction region is influenced in a manner similar to a time varying pumping field, field producing means for preventing the spread of said electron beam in a predetermined direction orthogonal to the direction of flow of said electron beam, said signal input coupling means responsive to an input signal to produce deflections of said electron beam in a direction orthogonal to both said predetermined direction and the direction of flow of said electron beam, said interaction region adapted to increase said deflection of said electron beam as said electron beam traverses said interaction region and said output signal coupling means responsive to said deflections in said electron beam to produce an output signal that is an amplified signal representative of said input signal.

10. A microwave amplifier comprising means for projecting a plurality of parallel electron beams along a plurality of parallel axes, a signal input coupler, spaced electrodes defining an interaction region and a signal output coupler spaced along each of said axes, means for impressing a direct current potential along said spaced electrodes to establish a direct current field in said interaction region which varies along the path of said electron beam such that an electron passing through said interaction region is influenced in a manner similar to a time varying pumping field, field producing means for preventing the spread of each of said electron beams in a predetermined direction orthogonal to the direction of flow of said electron beam, said signal input coupling means responsive to input signals to produce deflections of said electron beams in a direction orthogonal to both said predetermined direction and the direction of flow of said electron beams, said interaction region adapted to increase said electron beams deflections as said beams traverse said interaction region and said output signal coupling means responsive to said deflections in said electron beams to produce an output signal that is an amplified signal representative of said input signal.

11. A microwave amplifier comprising means for projecting a plurality of electron beams along a plurality of parallel axes, a signal input coupler, spaced electrodes defining an interaction region and a signal output coupler spaced along each of said axes, means for impressing a direct current potential on said spaced electrodes to establish a direct current field in said interaction region which varies along the path of said electron beams such that an electron passing through said interaction region is influenced in a manner similar to a time varying pumping field,

12

field producing means for preventing the spread of said electron beams in a predetermined direction orthogonal to the direction of flow of said electron beams, said electron beams being in a side-by-side relation, said signal input coupler responsive to an input signal to produce deflections of said electron beams in a direction orthogonal to both said predetermined direction and the direction of flow of said electron beams, said interaction regions adapted to increase said deflections of said electron beams as said electron beams traverse said interaction regions and said output signal coupling means responsive to said deflections in said electron beams to produce an output signal that is an amplified signal representative of said input signal.

12. A microwave amplifier comprising means for projecting a plurality of electron beams along a plurality of parallel axes, a signal input coupler, spaced electrodes forming an interaction region and a signal output coupler spaced along each of said axes, said electron beam axes arranged in a circular fashion, means for applying a direct current voltage to said spaced electrodes to establish a direct current field in said interaction region which varies along the path of said electron beam such that an electron passing through said interaction region is influenced in a manner similar to a time varying pumping field, field producing means for preventing the spread of each of said electron beams in a predetermined direction orthogonal to the direction of flow of said electron beams, said signal input coupling means responsive to an input signal to produce deflections of said electron beams in a direction orthogonal to both said predetermined direction and the direction of flow of said electron beams, said interaction regions adapted to increase said deflections of said electron beams as said electron beams traverse said interaction regions and said output signal coupling means responsive to said deflections in said electron beams to produce an output signal that is an amplified signal representative of said input signal.

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