

March 1, 1960

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2,927,243

ELECTRON DISCHARGE DEVICE FOR SIGNAL TRANSLATION

Filed Jan. 23, 1956

3 Sheets-Sheet 1

FIG. 1A

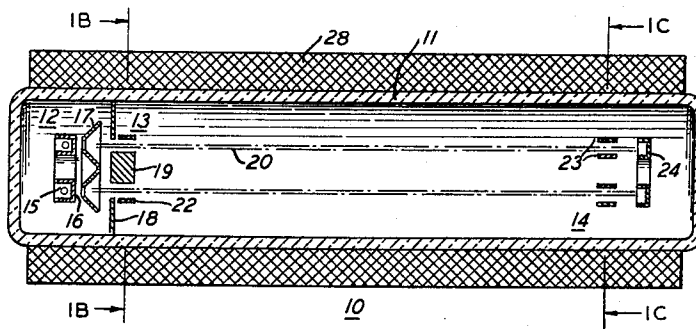


FIG. 1B

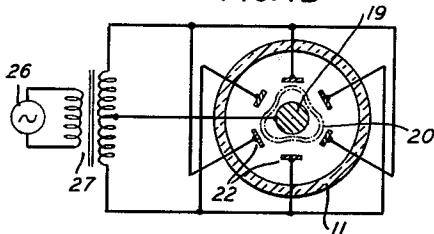


FIG. 1C

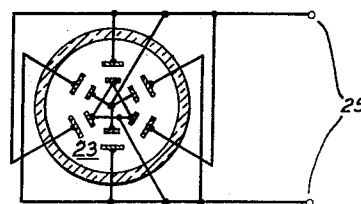


FIG. 2A

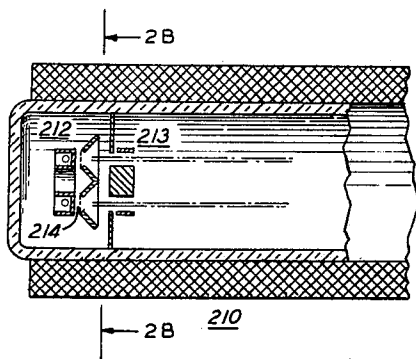
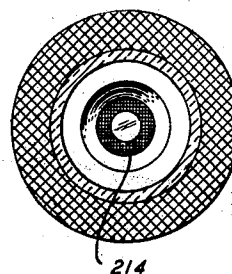


FIG. 2B



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FIG. 3A

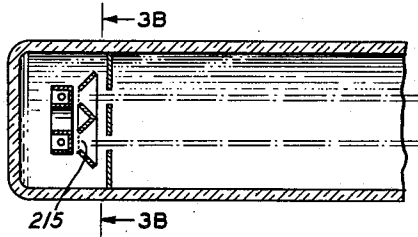


FIG. 3B

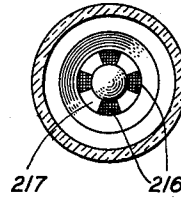


FIG. 4A

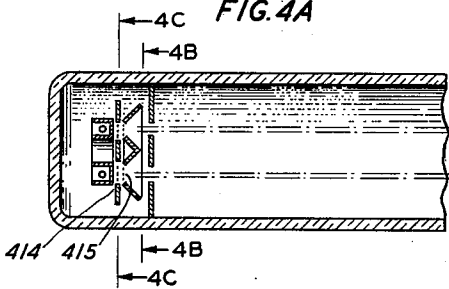


FIG. 4B

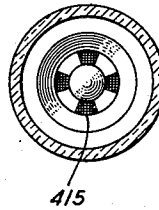


FIG. 4C

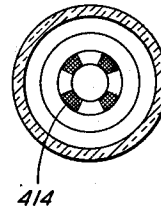


FIG. 5A

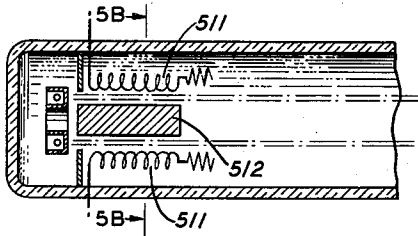


FIG. 5B

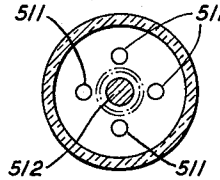


FIG. 6A

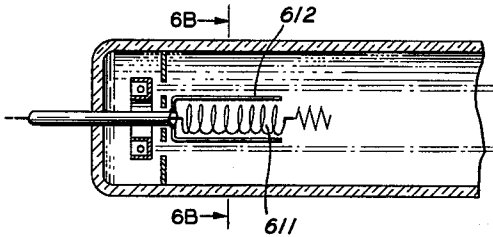
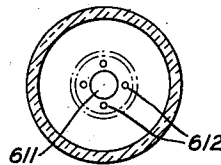


FIG. 6B



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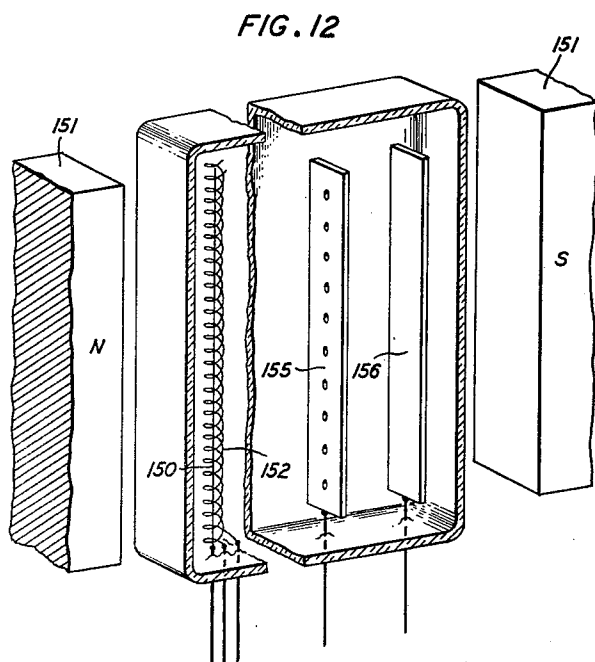
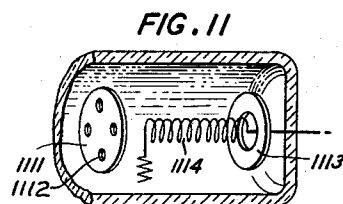
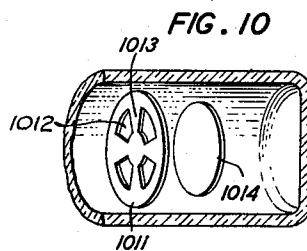
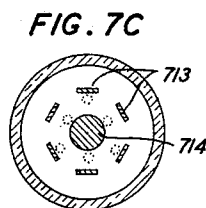
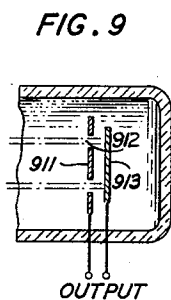
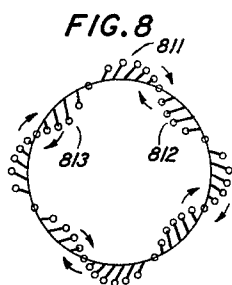
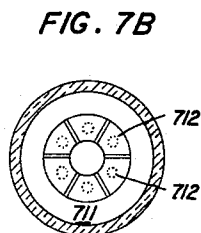
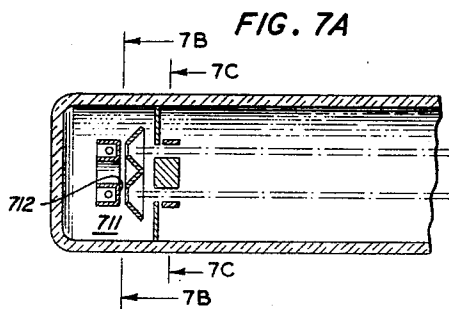
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ELECTRON DISCHARGE DEVICE FOR SIGNAL TRANSLATION

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3 Sheets-Sheet 3



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ELECTRON DISCHARGE DEVICE FOR
SIGNAL TRANSLATION

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Application January 23, 1956, Serial No. 560,547

12 Claims. (Cl. 315—30)

The present invention relates to an electron discharge device useful for obtaining electrical signal translation.

A principal object of the present invention is to achieve in a single device satisfactory signal translation over both high and low frequencies.

A related object is to achieve high gain over a wide range of frequencies in a single device.

To these ends, the present invention employs a novel technique for achieving amplification. The technique involves projecting an annular or ribbon electron beam which has a thickness which is small compared to its circumference or width into a magnetic field for flow along an extended path in the direction of the flux lines of the field and modulating this beam periodically along its circumference or width by an input transducer in accordance with variations in an applied signal. In particular, the input transducer functions so that periodically along the circumference or width of the beam, different electrons are modulated to a different extent in accordance with applied signals. Such modulation takes the form of deflection initially either in a direction parallel to the circumference or width dimension or in a direction parallel to the thickness dimension. However, because of both space charge effects and the presence of the magnetic field, all such deflections eventually give rise to a spiral rotation of the affected electrons. The net effect is that the beam tends to develop into a series of spiral nebulae; there is a tendency to degeneration of the beam into discrete portions having different rotation characteristics in accordance with the applied signal. Moreover, it is found that the amplitude of the disturbances on the beam increases with travel in the longitudinal magnetic field and that such increase is exponential along the beam length. Accordingly, an amplified output signal may be extracted from the beam by a suitable output transducer responsive to the disturbance on the beam.

Such operation is clearly to be distinguished from that familiar in beam-deflection tubes where the whole beam is deflected transversely a uniform amount in accordance with variations in an applied signal.

The principal feature of the present invention is a combination for use in amplification which includes means for projecting an annular or ribbon electron beam in the direction of a magnetic field, an input transducer for modulating the beam along its circumference or width in accordance with an applied signal, and an output transducer responsive to the resultant disturbances on the beam, the output transducer being spaced from the input transducer downstream along the path of flow a sufficient distance to permit the initial modulation to increase, whereby the output signal extracted is an amplified replica of the signal applied to the input transducer. Moreover, the input transducer is characterized in that it converts signals applied thereto to a relative displacement of different electrons along the beam circumference or width. As herein used, the term upstream is used to signify proximity to the electron source whereas the term

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downstream is used to signify proximity to the collector.

Subordinate features of the present invention are novel transducers for modulating an annular or ribbon beam in the manner described and novel transducers for extracting an output signal from the resulting disturbances on an electron beam.

In one amplifier embodiment of the invention, an annular beam is projected into a longitudinal magnetic field for travel parallel to the flux lines thereof. An input transducer is positioned adjacent the upstream end of the beam and includes a series of deflection plates arranged symmetrically around the periphery of the annular beam for applying in accordance with signal information deflections to the beam which are periodic in a circumferential direction and which give rise to signal modulation of the beam. An output transducer is positioned adjacent the downstream end of the beam for extracting an amplified signal from the modulations on the beam and includes a like series of pairs of plates spaced symmetrically around the periphery of the beam, one plate of each pair being within the quiescent position of the beam and the other without.

In a second amplifier embodiment, a ribbon beam is projected for travel parallel to the flux lines of a longitudinal magnetic field, and input and output transducers are positioned adjacent the upstream and downstream ends of the beam, respectively. The input transducer in this case advantageously is a bifilar helix which comprises two equi-pitch helical conductors interwound along a common axis. A filamentary cathode is positioned along such common axis and electrons emitted therefrom are formed into a ribbon beam which passes through the bifilar helix, being modulated in a direction along its width by a signal applied between the two conductors of the helix. The beam continues through a magnetic field space where the modulations grow and then passes an output transducer which extracts the output signal from the beam modulations. The output transducer in this case advantageously is a conductive sheet which is positioned to intercept the beam and has a series of apertures therethrough.

Various other illustrative embodiments will also be described.

The invention will be better understood from the following more detailed description taken in conjunction with the accompanying drawings in which:

Fig. 1A is a longitudinal-sectional view of an amplifier embodiment of the present invention;

Figs. 1B and 1C are cross-sectional views of the amplifier of Fig. 1 taken through lines B—B and C—C, respectively;

Figs. 2A, 3A, 4A, 5A, and 6A are longitudinal-sectional views, each showing the upstream portion of a tube of the general type shown in Fig. 1 but incorporating a different form of input transducer;

Figs. 2B, 3B, 4B, 4C, 5B and 6B show sectional views of the various tubes shown in Figs. 2A through 6A;

Fig. 7A is a longitudinal-sectional view of a portion of a tube which is of the general type shown in Fig. 1 but which employs a plurality of pencil beams arranged in a circular array to form in effect an annular beam and Figs. 7B and 7C are sectional views of the tube shown in Fig. 7A;

Fig. 8 is a sketch useful for purposes of explanation showing in cross section an annular electron beam which has been modulated in accordance with the present invention;

Each of Figs. 9, 10 and 11 shows an alternative form of an output transducer; and

Fig. 12 shows in cut-away perspective an embodiment of the invention employing a ribbon beam.

In general, there has been employed a minimum of

reference numerals in the drawing, and in particular there is usually avoided the giving of reference numerals to elements corresponding to elements previously given reference numerals in a previously described figure.

Referring now more particularly to the drawings, Fig. 1A shows, by way of example, an amplifier tube 10 comprising an evacuated envelope 11 enclosing an electron gun 12 for forming an annular electron beam and input and output transducers 13 and 14, respectively, positioned at the upstream and downstream ends of the beam path. The gun includes a heater 15, an annular cathode 16, a beam forming electrode 17 having an aperture aligned with the emissive portion of the cathode surface, and an accelerating anode comprising the outer plate 18 and the inner cylinder 19 which between them form an aperture aligned with the emissive surface for passage therepast of the electron beam 20. The input transducer comprises a circular array of deflection plates 22 disposed symmetrically around the cylinder 19. The input transducer serves to apply deflection forces periodically about the beam's circumference as shown more clearly in Fig. 1B. It is characteristic that the spacing of the deflection forces is such that the space period of the deflection forces or the wavelength of the deflecting field along the beam's circumference be small compared to the wavelength of the signal to be amplified. The deflection forces give rise to disturbances on the beam whose amplitudes increase exponentially along the length of the beam because of the combined effect of space charge forces and the magnetic field. As is shown in Fig. 1B, input signals are applied from source 26 to the input winding of transformer 27. Each terminal of the secondary winding of the transformer is connected to a different set of alternate plates of the array 22 and the center tap is connected to the inner cylinder 19. Output transducer 14 includes a like circular array of a pair of conductive plates 23 positioned for extracting output signals from the disturbances on the beam. As is shown in Fig. 1C, the plates 23 are disposed to form inner and outer circular arrays of plates and each set of alternate plates of the inner array is interconnected with a set of alternate plates of the outer array and an output terminal 25. A collector 24 is positioned beyond the plates 23 and serves to collect any current which passes through the plates.

Support members for the various elements of the tube have been omitted in the drawing for simplicity. Moreover, there is also omitted the lead-in conductors from suitable voltage sources required for maintaining appropriate potentials on the various tube elements. In operation, the cathode is biased to a potential slightly positive with respect to the beam focusing electrode and appreciably negative with respect to the accelerating anode and the various elements of the input transducer so that the beam will be projected toward the opposite end of the envelope, toward the output transducer and collector which also are biased positively with respect to the cathode.

Additionally, a solenoid 28 is provided surrounding envelope 11 for establishing a magnetic field whose flux extends along the length of the beam path for providing forces on the beam sufficient to focus the beam in the absence of signal modulations and for cooperating with the space charge forces on the beam for amplifying signal disturbances provided on the beam of the kind described.

In operation, during one half cycle of a signal applied by the input source, the potential of one set of alternate plates of the array 22 will be less than that of the inner cylinder 19 while the potential of the other set of alternate plates will be greater than that of cylinder 19. This results in a radial force on the electrons of the beam which varies inwardly and outwardly periodically around the circumference of the beam and serves to distort the beam which was initially annular to the shape shown in Fig. 1B. During the next half cycle, the potentials

on alternate sets of plates are reversed, and the beam is affected accordingly. This disturbance is found thereafter to build up exponentially along the beam length in the presence of the magnetic field. The plates 23 of the output transducer are disposed so that in the absence of modulation on the beam, the beam will pass almost completely through the interspace between each pair of plates 23 and no appreciable output voltage will be set up across output terminals 25. However, if the beam has been disturbed or modulated by application of an input signal, electrons will be intercepted by the plates 23 and an output voltage developed across terminals 25. In particular, during the time corresponding to one-half of the applied signal cycle, the current will be intercepted by one half of the plates including one set of alternate outer plates and one set of alternate inner plates and during the time of the other half cycle by the other half of the plates including the other sets of alternate inner and alternate outer plates. Thus the signal modulations on the beam are converted into alternating current flow through any load connected across terminals 25.

It has also been found that the amount of transverse beam deflection initiated by deflection arrangement 13 is a function of the amount of current in the beam. For constant deflection fields, an increase in beam current results in greater initial beam deflection, and, conversely, a decrease in beam current results in a smaller initial beam deflection. This property may advantageously be employed to provide an alternative technique for modulating the electron beam, which, in fact, may be preferred for many applications. Such a technique is employed in the tube shown in Figs. 2A and 2B. Only the input section of this tube has been shown since the output transducer may be of the type shown in Fig. 1C.

The tube 210 shown in Figs. 2A and 2B includes an evacuated envelope, electron gun, and an input transducer 213. The electron gun is substantially of the same type as that of Fig. 1A but includes a control grid 214 which is associated with the beam forming electrode of the gun for greater control of the electron emission from the gun. The input transducer includes a deflection arrangement made up of a circular array of plates as that shown in Fig. 1B. However, in this case, the input signal is applied directly to the control grid to modulate the potential of the control grid and thereby vary the beam density, and the deflection arrangement is used to set up electrostatic fields. To this end, one set of alternate plates of the array is kept at a fixed potential greater than that on the inner cylinder of the deflection arrangement and the other set is kept at a fixed potential less than that of the inner cylinder. This results in a constant distorting field on the annular beam. However, the extent of distortion of the beam shape is now increased or decreased as the current of the beam is correspondingly increased or decreased. Thus the disturbance of the beam will vary again in accordance with the applied signal. In the operation of this tube, the input transducer comprises both the deflection arrangement and the gun control grid. The modulations thereby produced on the beam may be extracted by a suitable output transducer, for example, of the kind shown in Fig. 1C.

Figs. 3A and 3B show a portion of a tube employing a third technique for modulating an annular beam in a manner characteristic of the principles of the invention. This technique utilizes an unbalance in the space charge forces in the beam to produce disturbances periodically around the circumference which, in turn, because of the magnetic field results in a distortion of the beam of the kind useful for signal amplification. Consider a uniform annular beam passing in equilibrium along the parallel flux lines of a magnetic field. If the electron beam density is thereafter decreased over one small segment of the annular beam, the electrons in the beam at the boundaries of that segment experience unbalanced space charge forces directed generally to-

ward the lower density segment. Such forces in the presence of a magnetic field result in the radial displacement of the boundary electrons which, in turn, creates additional space charge forces and thus additional displacements, etc., to effect an exponential build-up of the disturbance along the beam length. By providing, spaced around the circumference of the beam, several such segments of decreased current density, the disturbances initiated may be made to produce modulation on the beam of the type described with reference to Fig. 1B. Alternatively, by providing spaced around the circumference of the beam several segments of increased current density, the same effect can be achieved. In the tube shown in Figs. 3A and 3B, a variation of current density periodically around the circumference of the annular beam is achieved by a segmented control grid 215 positioned advantageously adjacent the electron source. This grid, as shown more clearly in Fig. 3B contains grid wires 216 over certain segmental portions of its annular aperture 217 and thus the current density of the beam in these segmental regions is affected by the voltage on the grid to a greater degree than in the regions therebetween. In operation, source 26 serves to apply a signal voltage between cathode 16 and control grid 215. As a result of the consequent variation in current density over the beam circumference, modulations are produced on the beam resulting in beam distortion of the same character as described with reference to Fig. 1B. In this embodiment, the segmented grid serves as the input transducer. Thereafter, from the modulations thus produced an output voltage may be extracted downstream along the beam by a suitable output transducer, for example of the kind shown in Fig. 1C.

Figs. 4A, 4B and 4C show a modification of the tube of Figs. 3A and 3B employing as the input transducer two segmental grids 414 and 415 spaced apart along the annular beam. In the construction of this tube the grid portions of these control grids are out of alignment along the path of flow, allowance being made for any spiral motion of the electrons so that any given segment of the annular beam will pass through the grid portion of one or the other of the two control grids but not both. Consequently, as the annular beam passes the grids, one set of alternate segmental portions is affected by the first grid 414 and the other set of alternate segmental portions is affected by the second grid 415. Advantageously, a push-pull input signal arrangement of the kind shown in Fig. 1B is then provided for applying the signal voltage to each grid in opposite phase with respect to the cathode. The net effect is that the beam is distorted by applied signals in the manner similar to that provided by the arrangement in Fig. 1B.

Figs. 5A and 5B and 6A and 6B show alternative embodiments for establishing modulations of the kind desired on an annular beam by the use of deflection arrangements of the so-called distributed type which are of special utility at high frequencies. In the embodiment shown in Figs. 5A and 5B, deflection of the beam is provided by four helices 511 spaced around the beam symmetrically about conductive cylinder 512 positioned within the beam. In some instances, it may be desirable to vary the direction of the axes of the helices to make allowance for the circumferential component of beam velocity arising from the magnetic field so that each helix interacts with the same group of electrons throughout its length. Although each helix is advantageously a plurality of signal wavelengths long, the spacing around the beam is such that the wavelength of the deflecting field around the circumference of the beam is less than the signal wavelength. Each helix advantageously is terminated to be substantially reflectionless. The signal to be amplified is supplied from a signal source and applied in-phase to the upstream end of each of the helices. Because of coupling between the wave on the

helix and the electrons proximate thereto, there are established forces periodic around the circumference of the beam which distort the beam in accordance with the applied signal. It is advantageous to match the longitudinal velocity of the beam past the helices to the axial velocity of the wave on each helix to provide forces on the beam which are cumulative in the axial direction. In this instance it may be advantageous to employ an output transducer which is similar in structure to the input transducer.

In the tube of Figs. 6A and 6B, deflection of the beam periodically around its circumference is provided by a single helix 611 and four conductive rods 612 are spaced symmetrically about its periphery to provide a circumferential variation in the coupling between the beam and the wave traveling along the helix. The signal to be amplified is applied between the helix and the conductive rods. By this arrangement also, there is provided distortion around the circumference of the beam in accordance with applied signals and in the magnetic field because of space charge effects this disturbance will grow so that a suitable output transducer will be able to extract an amplified replica of the signal.

Figs. 7A and 7B show a modification of the tube of Fig. 1 in which the modification comprises the replacement of a gun for producing a continuous annular beam with a gun for providing a plurality of pencil beams arranged in a circular array to form the equivalent of an annular beam. Electron gun 711 for forming the pencil beams is shown schematically as including a cathode which includes a plurality of emissive regions 712 spaced in a circular array. Advantageously, each beam has associated with it its own focusing electrode. Each of the pencil beams thus formed is projected through the interspace between one of the deflection plates 713 and inner conductive cylinder 714 of an input transducer which may be of the kind discussed hereinabove whereby it is deflected in accordance with an applied signal as previously described. Operation of this tube is substantially the same as that previously described. The plurality of pencil beams may be considered as forming a composite annular beam initially having a nonuniform current density over its cross section. The use of pencil beams does, however, have particular advantages in that it facilitates construction of a suitable electron gun, and further it militates against the beam breaking into a greater number of periods than desired.

Before discussing output transducers which may be used in place of the transducer of Fig. 1C for abstracting the signal modulation from the beam, it may be helpful to discuss in more detail the nature of the displacement of electrons of the beam as a result of signal modulation of the kind described. Fig. 8 is intended to illustrate the deflection paths of individual electrons of an annular beam in a longitudinal magnetic field when acted on by deflection forces periodic around its circumference. In particular, it is to be noted that the presence of the magnetic field results in a tangential component of velocity which adds to the radial component of velocity resulting from the radial electric fields. Moreover, electrons 811 at a portion of the beam on which radially inward fields are acting are deflected in a direction substantially opposite to that of electrons 812 or electrons 813 at portions of the beam on which radially outward fields are acting. In particular, electrons 811 and 812 move closer together whereas electrons 811 and 813 move farther apart, whereby density modulations occur around the circumference. Moreover, there is a tendency for the beam to separate into spiraling segments as shown by the arrows when overload is reached. The space period of such modulations on the beam can be controlled by controlling the space period of the deflection fields applied to the beam, for example by varying the number of deflection plates in the transducer of Fig. 1B, or by varying the number of helices in the transducer of Fig. 5, and such space period is inde-

pendent of the frequency of the applied signal. This independence between the space period and the frequency of the applied signal is an important characteristic of such because the applied signal tends to produce longitudinal modulations on the beam in addition to the circumferential modulations it produces with the transducers discussed herein. For the avoidance of intermodulation effects which would obscure the signal, it is important that the space period of the circumferential modulation be less, and preferably substantially less, for example one tenth, than the space period of the longitudinal modulations. Thus it is important that the spacing of deflection elements around the circumference be such that oppositely directed deflection fields set up by such elements be less than one half the wavelength of the applied signal.

Appreciation of the fact that as the result of signal modulation the beam has both radial and tangential deflection components, each of which is a measure of the amplitude of the initial disturbance, facilitates an understanding of the requirements of a suitable output transducer.

The output transducer shown in Fig. 9 is one primarily responsive to the radial components of signal modulation. It comprises a first conductive plate 911 having an annular aperture 912 therethrough and a second conductive plate 913 positioned to intercept the electrons which pass through aperture 912. In one mode of operation, the beam is aligned to pass essentially completely through aperture 912 in the absence of any signal modulation. Then as a signal is applied to modulate the beam, the amount of beam current which continues through the aperture decreases in proportion to the extent of radial deflection of the beam. Thus the amount of current reaching plate 913 varies in accordance with the level of the signal applied to modulate the beam (actually in accordance with the absolute value of the level of the applied signal since the beam current reaching plate 913 varies in the same manner for both the positive and negative swing of the applied signal). The current reaching plate 911 is also a measure of the signal.

In another mode of operation, a D.-C. bias is employed to establish a steady initial disturbance on the beam and the beam thereafter is aligned such that only half the beam current will pass through the annular aperture. In this case, as a signal is applied, the modulation on the beam is decreased on the negative swing of the applied signal and increased on its positive swing so that the output current reaching conductor 913 will now vary linearly in accordance with the level of the signal applied to modulate the beam.

Fig. 10 shows an alternative output transducer responsive to both the radial and tangential components of signal modulation on the beam electrons for deriving an output signal therefrom. This transducer comprises a first conductive plate 1011 having an annular aperture 1012 interrupted by radial segments 1013, and a second conductive plate 1014 positioned to intercept the electrons which pass through aperture 1012. The plates are aligned for maximum transmission past the plate 1011 in the absence of signal modulation on the beam. Signal modulation on the beam will thereafter vary the amount of current arriving at plate 1014 in accordance with such modulation.

Fig. 11 shows an alternative output transducer especially advantageous for use at high frequencies in deriving signal from the modulated beam. This transducer includes a first conductive plate 1111 having a series of apertures therethrough in a circular array, a second conductive plate 1113 positioned to intercept beam current which passes through such apertures, and a helical conductor 1114 positioned between the two plates and terminated at the upstream end in its characteristic impedance, and leading off to the load at its downstream end. The helical conductor serves to form a distributed type wave circuit. As previously explained, the amount of current

passing through apertures 1112 may be made to vary in accordance with the signal modulation on the beam. In this instance, the modulation on the beam is converted into density modulation in the current passing beyond the plate 1111. Such density modulation on the beam may be made to set up a traveling wave on the helical conductor if the longitudinal velocity of the beam is adjusted to match the axial velocity of a wave induced in the helix in accordance with principles familiar in the traveling wave tube art. For increased efficiency the variations in current arriving at the plate 1113, which is another measure of the output signal, may be used to augment the wave set up on the helix.

The discussion up to this point has been concerned primarily with devices which employ annular electron beams. However, the general principles set forth also are applicable to devices employing a ribbon beam having a thickness small compared to its width. In this case there is provided a deflection arrangement which deflects the beam periodically along its width in accordance with an applied signal. To this end, it is feasible to employ deflection arrays of the kind described with the simple modification of having the deflecting elements positioned in a linear array along the beam width rather than in a circular array along the beam circumference. The output transducer similarly would be modified to be responsive to the signal modulation on such a ribbon beam. The use of a ribbon beam also makes advantageous the use of an input transducer in which the deflection fields established by the applied signals tend in the absence of a magnetic field to displace the electrons in a direction parallel to the wide dimension of the beam. In Fig. 12, there is shown schematically a tube of this kind.

In the tube of Fig. 12, a ribbon beam is provided by the filamentary cathode 150. Suitable means not shown of the kind familiar to a worker in the art are associated with the cathode for forming the cathode emission into a ribbon beam and directing it in the longitudinal direction desired for flow parallel to a magnetic field provided by the permanent magnet 151 which surrounds the tube envelope. The input transducer comprises a bifilar helix 152 comprising a pair of equipitch interwound helices having a common axis and equal diameters. Advantageously, the filamentary cathode is positioned along the common axis.

Input signals are applied by way of a balanced pair line to one end of the bifilar helix so that corresponding points on contiguous turns of the two helices are substantially 180 degrees out of phase. The opposite end of the bifilar helix is advantageously made reflectionless. Excitation of this type provides at the region of exit of the ribbon beam from the surrounding bifilar helix an electric field which extends in the wide dimension of the beam and which alternates in direction with a space period therealong equal to the pitch of a single helical conductor.

Such a field provides forces, in accordance with signal modulation in the direction of the wide dimension of the beam, which reverse direction periodically therealong. It is important that the pitch of the bifilar helix (which is twice the pitch of each helical conductor) is small compared to the wavelength of the applied signal. Such forces tend to deflect electrons in the beam and the presence of the magnetic field results in a displacement in the thickness dimension of the beam in a manner analogous to displacements previously described. Because of space charge effects, such displacements grow with beam travel in the magnetic field.

Downstream along the path of travel, an output transducer is used to extract an amplified output signal from the modulation on the beam. As shown, the output transducer comprises a conductive plate 155 which includes a series of apertures in a linear array and spaced apart a distance corresponding to the pitch of a single helix of the bifilar helix of the input transducer. The

holes are aligned with the position of the electron beam in the absence of signal modulation and have a diameter wider than the width of the electron beam in the absence of signal modulation. Beyond this plate is positioned a collector 156 which collects all current passing through the plate 155. Signal modulation of the beam will vary the amount of current reaching the collector in accordance with such modulation.

This arrangement is useful only at frequencies at which the total length of the bifilar helix of the input transducer is small compared to the signal wavelength. At higher frequencies, it is advantageous to interpose between the plate 155 and the collector 156 a distributed wave circuit such as a single wire helix whose axis is aligned with the apertures such that the current passing through such apertures sets up a traveling wave on the helix. In this case, one end of such helix is made substantially reflectionless and the other end is coupled to utilization apparatus. In such an arrangement, the phase propagating characteristics of the output helix should be matched to the phase propagating characteristics of the input bifilar helix and each is made a plurality of wavelengths of the applied signal long.

Alternatively, it is feasible to substitute a bifilar helix of the kind used as the input transducer for the output transducer, terminating one end to make it reflectionless and abstracting the amplified wave from the other. In such an arrangement the apertured plate 155 and the collector are omitted and the spent electrons are collected by the bifilar helix.

It should be evident that the specific embodiments described are merely illustrative of the general principles involved. Various other arrangements may be devised by one skilled in the art without departing from the spirit and scope of the invention. In particular, it would be feasible in transducer arrangements of the kind shown in Fig. 1B to employ each plate as a separate channel advantageously in conjunction with a multipencil beam gun and apply a separate signal to each channel. The output transducer similarly would be adjusted to derive separate outputs from each pencil beam.

In the succeeding claims, the term "transverse dimension of the beam" is used generically to mean both the width of a ribbon beam and the circumference of an annular beam.

What is claimed is:

1. In combination, means for forming an electron beam for flow in a magnetic field along a substantially constant longitudinal path of flow, means upstream along the path of flow for modulating the beam periodically along its transverse dimension symmetrically with respect to said path in accordance with signal information with a space period less than the wavelength of the applied signal and creating signal disturbances on the beam which grow with beam travel in the magnetic field, and means downstream along the path of flow responsive to such signal disturbances for providing an output therefor.

2. In combination, means for forming an annular electron beam for flow in a magnetic field along a substantially constant longitudinal path of flow, means upstream along the path of flow for modulating the beam periodically along its circumference and symmetrically with respect to said path in accordance with signal information with a space period less than the wavelength of the applied signal and creating signal disturbances around the circumference of the beam which grow with beam travel in the magnetic field, and means downstream along the path of flow responsive to such signal disturbances for providing an output therefor.

3. In combination, means for forming a ribbon electron beam for flow in a magnetic field along a substantially constant longitudinal path of flow, means upstream along the path of flow for modulating the beam periodically along its width dimension and symmetrically with respect to said path in accordance with signal infor-

mation with a space period along the width dimension less than the wavelength of the applied signal and creating signal disturbances on the beam which grow with beam travel in the magnetic field, and means downstream along the path of flow responsive to such signal disturbances for providing an output therefor.

4. In combination, means for forming an electron beam for flow in a magnetic field along a substantially constant longitudinal path, means upstream along the path of flow for modulating the beam periodically along its transverse dimension and symmetrically with respect to said path in accordance with signal information including a plurality of deflection means spaced apart along the transverse dimension of the beam with a spacing less than one-half the wavelength of the applied signal for creating signal disturbances on the beam which grow with beam travel in the magnetic field, and means downstream along the path of flow responsive to such signal disturbances for providing an output therefor.

5. In combination, means for forming an annular beam for flow in a magnetic field along a substantially constant longitudinal path of flow, an input transducer upstream along the path of flow comprising a plurality of deflection means spaced apart around the circumference of the beam for modulating the beam periodically along its circumference and symmetrically with respect to said path in accordance with signal information for creating signal disturbances on the beam which grow with beam travel in the magnetic field, and an output transducer downstream along the path of flow responsive to such signal disturbances.

6. In combination, means for forming a ribbon beam for flow in a magnetic field along a substantially constant longitudinal path of flow, an input transducer upstream along the path of flow comprising deflection means spaced periodically along the beam's width for modulating the beam periodically along its width and symmetrically with respect to said path in accordance with signal information with a space period less than the wavelength of the applied signal for creating signal disturbances on the beam which grow with beam travel in the magnetic field, and an output transducer downstream along the path of flow responsive to such signal disturbances.

7. In combination, means forming an annular electron beam for flow in a magnetic field along a substantially constant longitudinal path of flow, input means upstream along the path of flow including a series of conductive means spaced apart around the circumference of the beam for simultaneously deflecting circumferentially spaced portions of the beam in different radial directions transverse to the path of flow in accordance with signal information for creating signal disturbances on the beam which grow with travel in the magnetic field, and output means downstream along the path of flow responsive to the signal disturbances.

8. In combination, a bifilar helix adapted to be excited by signal information so that the potential corresponding points of contiguous turns of its two conductors is out-of-phase, a filamentary cathode positioned along the axis of the bifilar helix for providing a ribbon beam for flow in a magnetic field along a substantially constant path and for exit through said bifilar helix whereby the beam is modulated periodically along its width and symmetrically with respect to said path in accordance with the signal information with a space period less than the wavelength of the applied signal, and output means along the path of flow responsive to the signal modulation on the beam.

9. In combination, means forming an electron beam for flow in a magnetic field along a substantially constant longitudinal path of flow, a plurality of means spaced apart along the transverse dimension of the beam and supplied with input information, alternate means being excited in phase and adjacent means out of phase,

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whereby the beam is modulated periodically along its transverse dimension and symmetrically with respect to said path, and output means responsive to the beam modulation.

10. In combination, means forming an annular beam for flow in a magnetic field along a substantially constant longitudinal path of flow, a plurality of plates spaced apart around the circumference of the beam upstream along the beam and excited by signal information, adjacent plates being excited in opposite phase and alternate plates in phase whereby the beam is modulated periodically around its circumference and symmetrically with respect to said path in accordance with signal information, and output means downstream along the beam responsive to the modulation on the beam.

11. In combination, means forming an annular beam for flow in a magnetic field along a substantially constant longitudinal path of flow, a plurality of helices spaced apart around the circumference of the beam each having its axis extend in the direction of the path of flow and having a characteristic axial velocity substantially equal to the beam velocity for modulating the beam periodically around its circumference and symmetrically with respect to said path in accordance with signal information with a space period less than the wavelength of the applied signal, and output means responsive to the signal modulation on the beam.

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12. In combination, means forming an electron beam having a thickness dimension substantially less than its widest cross-sectional dimension for flow in a magnetic field along a substantially constant longitudinal path, means for producing a plurality of distinct transverse bunches of electrons in the beam, said means including a plurality of spaced means upstream along the path of flow for modulating said beam periodically along its transverse dimension in response to signal information, said last-mentioned means having a transverse space period with respect to said path less than the wavelength of the applied signal, and output means downstream along the path of flow responsive to the signal modulations on the beam.

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