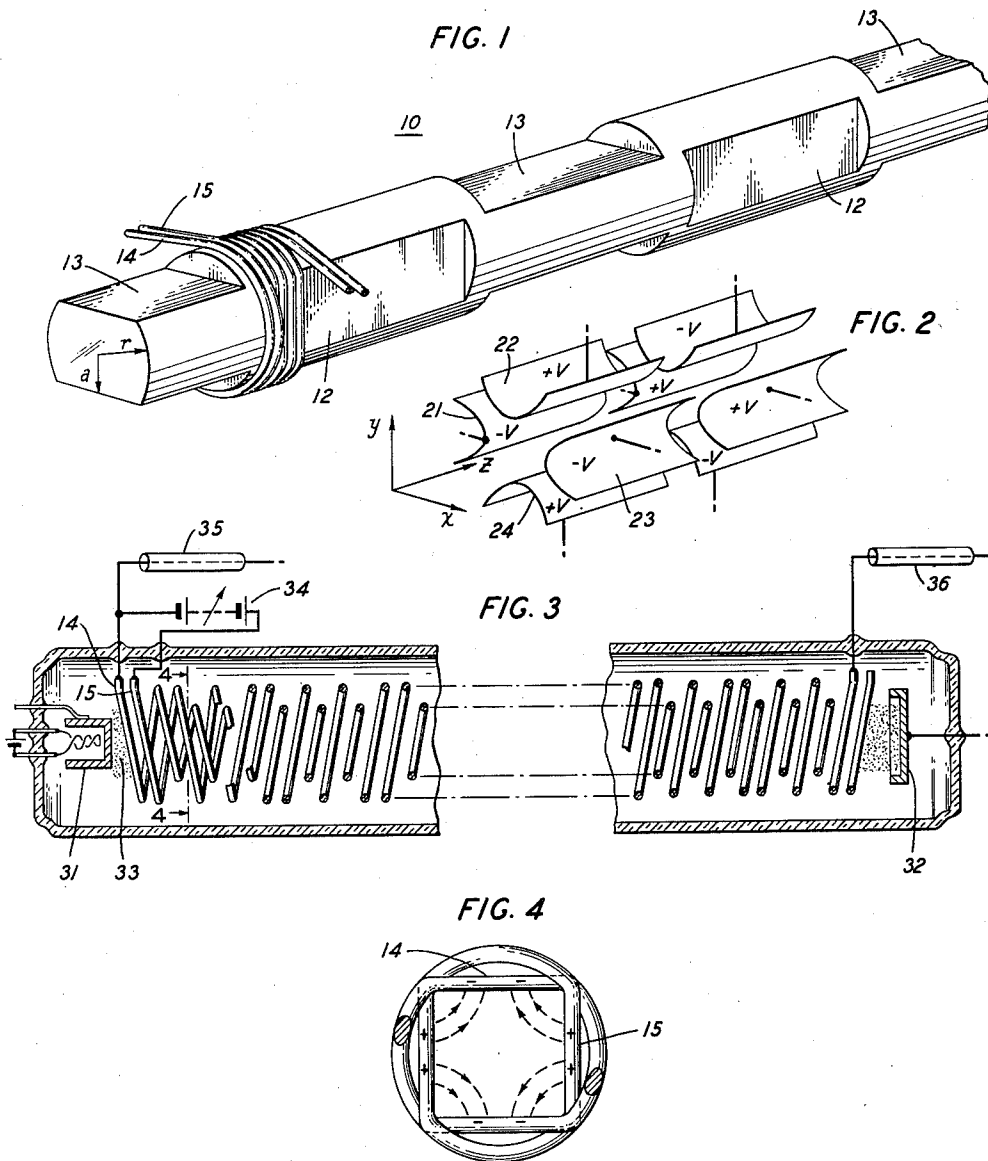


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TRAVELING WAVE TUBE
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TRAVELING WAVE TUBE

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This invention relates to electron beam focusing and more particularly to such focusing in traveling wave tubes.

In traveling wave tubes, an electromagnetic wave propagates along an interaction circuit past which is projected an electron stream in field coupling relationship. Because of the relatively long length of the electron path and because of the space charge forces acting in an electron stream when the electron density is high, as is here desirable, it is generally advisable to provide focusing to keep the electron flow cylindrical during its travel past the interaction circuit. In the past, such focusing generally has been provided by establishing a longitudinal magnetic field along the beam path. However, in practice, the high fluxes required for good magnetic focusing have necessitated the use either of large permanent magnets or solenoids which have added much bulk and weight to traveling wave tube systems.

An object of this invention is to eliminate the necessity for a longitudinal magnetic field and thereby to effect a saving in the size and weight of the auxiliary equipment necessary for the operation of traveling wave tubes.

There has recently been developed a technique for focusing a beam of charged particles which has been described as "strong focusing" and which utilizes a transverse magnetic field which interacts with the longitudinal velocity of the charged particles to provide an inward force acting on the charged particles. However, in the free space occupied by a beam it is impossible to have transverse magnetic fields which cause all particles to be acted on by an inward force. If the beam is focused in one plane, there exists another plane perpendicular thereto where it is defocused. Strong focusing systems overcome this problem by providing a succession of magnetic field regions along the beam path and orienting the field in successive regions so that the beam is focused alternately in two mutually perpendicular planes. The strength and periodicity of the magnet sections are adjusted so that the excursions of the edge particles are small. In particular, it has been found advantageous to employ quadrupole types of magnets for establishing the successive magnetic field regions, successive magnets being rotated 90 degrees. Moreover, there have been developed electrostatic analogues which function in accordance with these same general principles, utilizing a series of quadrupole transverse electric field regions, the field directions being appropriately shifted along successive regions.

The present invention is directed to the application of electrostatic strong focusing techniques to traveling wave tubes. In particular, the invention permits the substitution of transverse electrostatic fields for longitudinal magnetic fields in focusing the electron beam and thereby effects a saving in size and weight of the auxiliary equipment necessary for operation of traveling wave tubes. Moreover, since the electric focusing field can readily be varied, optimum beam focusing in a traveling wave tube can readily be obtained.

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An important feature of the present invention is a novel form of interaction circuit which is especially well adapted for use with electrostatic strong focusing techniques. To this end, in one specific embodiment, the interaction circuit comprises a bifilar helix which has been wound upon a special round mandrel having successive pairs of flat surfaces therein each pair being rotated 90 degrees from an adjacent pair. After removal of the mandrel, the turns of one helix winding are rotated 90 degrees with respect to those of the other winding. Then by impressing a direct voltage between the winding there is provided along the interior of this structure a succession of regions of electric field corresponding to a quadrupole type configuration, each region being rotated 90 degrees from an adjacent region.

An interaction circuit of the kind described is particularly well suited for conventional traveling wave tube operation with all the attendant advantages thereof because a wave traveling down a bifilar helix can be made to interact continuously with an electron stream. Such a circuit may be also well suited for spatial harmonic operation in which the electromagnetic wave interacts periodically with the electrons. This latter mode of operation is useful in extending the upper frequency of operation of a traveling wave tube.

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

Fig. 1 is a perspective view of a convenient form of mandrel useful in winding one embodiment of a focusing circuit in accordance with the present invention;

Fig. 2 is a perspective view of hyperbolic electrodes arranged to produce a periodic quadrupolar electric field;

Fig. 3 is a schematic side view partly in section of a traveling wave tube embodying a bifilar helix wound on the mandrel of Fig. 1; and

Fig. 4 is a cross section of the helix in Fig. 3 taken as indicated therein by line 4—4.

Referring now more particularly to the drawings, the mandrel 10 shown in Fig. 1 consists of a cylindrical rod 11 upon which are cut successive pairs of opposing flat faces, or surfaces. One set of pairs, pairs 13, are angularly displaced 90 degrees from the other set, pair 12, so that each is rotated 90 degrees from an adjacent pair. These surfaces are symmetrically placed around the axis of rod 11 and separated therefrom by distance a which is approximately 0.7 of the radius r of rod 11.

Near the left end of mandrel 10 there are shown, to illustrate the method of forming a circuit thereon, several turns of a bifilar helix consisting of windings 14 and 15. After this helix has been wound to sufficient length upon the mandrel, the latter should be dissolved, or removed in a similar manner, so that winding 15 can be rotated 90 degrees with respect to winding 14. The focusing effect of a direct potential applied between the windings of a helix so formed will be substantially the same as that produced by the electrode configuration shown in Fig. 2.

Typically for electrostatic focusing in accordance with the spirit of the invention, there is desired an electrode configuration of the kind shown in Fig. 2 where the desired field pattern transverse to the flow of electrons is obtained by maintaining electrodes 21, 22, 23, and 24 at suitable direct potentials $+v$ and $-v$. The faces of the electrodes are hyperbolic and are positioned so that the electric field E is zero at the axis around which the electrodes are placed and so that the derivatives

$$\frac{dE_x}{dy} \text{ and } \frac{dE_y}{dx}$$

are equal and uniform. The electron beam in passing transversely through such a field configuration, that is,

moving parallel to the Z axis, along electrodes 21, 22, 23, and 24, tends to be focused in the xz plane and defocused in the yz plane. Alternatively, this action can be described as a compression into the xz plane and an expansion in the yz plane. To overcome this asymmetry, the field patterns are shifted 90 degrees periodically along the longitudinal path of flow so that the focusing is alternately in the yz and xz planes. The strength and periodicity of the successive regions of transverse electrostatic fields can be adjusted so that the excursions of the edge electrons in the electron stream are always small. For a beam radius of 0.75 millimeter, beam accelerating voltage of 1000 volts beam current of 10 milliamperes, axial periodicity of electron field of 1 centimeter and inner radius of the helix of 1.5 millimeters, a potential v of the order of 100 volts is sufficient for satisfactory focusing.

Fig. 3 is a schematic side view of a traveling wave tube embodying the bifilar helix formed as explained in connection with Fig. 1. Electron gun 31 and collector 32 are positioned so that electron stream 33 flows along the axis of this helix. At the left-hand end of the helix an adjustable direct potential supply 34 is connected between windings 14 and 15 for the purpose explained previously. A wave transmission line 35 can be connected to winding 14 at the gun end thereof in the event that conventional, or non-spatial harmonic, operation of the tube is desired. If for some reason, however, it is desired to excite the helices such as to provide strong spatial harmonic field components, an input signal can be applied to winding 15 180 degrees out of phase with the input to winding 14. For forward or backward spatial harmonic operation the pitch of the helix should be changed accordingly.

When the tube shown in Fig. 3 is operating as a conventional amplifier, a signal wave applied to winding 14 of the tube helix travels down the tube with an axial phase velocity that is substantially the same as that of the electron stream. As the wave travels along it gradually slows down a net number of electrons so that upon reaching output circuit 36 at the collector end of the tube its amplitude has increased. Electron stream 33 is confined within the helix by the focusing action of the static electric field supplied by battery 34. This battery is made adjustable in voltage so that under a given set of conditions optimum focusing can be obtained.

The static electric field between windings 14 and 15 will be approximately as indicated by the dotted lines shown in the slightly enlarged cross section of the helix shown in Fig. 4 taken along the line 4—4 in Fig. 3. While this field configuration departs somewhat from the ideal pattern which obtains with the electrode arrangement shown in Fig. 2, it will be satisfactory for most applications. Should a more exact pattern be required, surfaces 12 and 13 in Fig. 1 can be made hyperbolic instead of flat.

Beam focusing in the arrangement of Fig. 3 takes place alternately along planes that are at right angles to each other. It is apparent, however, that the period and angular rotation of these focusing planes may be set at different values, such as three planes per period at angles of 120, 240, and 360 degrees respectively.

While the foregoing will serve to illustrate the general principles of this invention it is not intended as a complete description thereof. Changes or modifications in the embodiment set forth will occur to those skilled in the art and may be made without departing from the spirit or scope of the invention.

What is claimed is:

1. In an electron beam device, means forming a path of electron flow, a wave propagating circuit along the path of flow comprising two coiled conductors, each having alternately along its length portions in which a first transverse dimension is larger than a second transverse dimension perpendicular to the first transverse dimension and portions in which the first transverse dimension is

smaller than the second transverse dimension, the two conductors being interwound so that the transverse dimensions of one conductor are small where the transverse dimensions of proximate portions of the other conductor are large and the transverse dimensions of said one conductor are large where the transverse dimensions of proximate portions of said other conductor are small, and means for applying a potential difference between the two conductors.

2. In an electron beam wave interaction device, means for forming and projecting an electron beam along an axis, focusing means disposed along said axis for alternately focusing said beam in a first plane parallel thereto for a portion of its travel along said axis and then in a different plane parallel thereto for a portion of its travel along said axis, said focusing means comprising at least two helically wound conductors, each helix having a flat sided cross section which periodically is angularly rotated along the length of said helix, means for applying a potential difference between said helices, and input and output signal transmission means connected to said focusing means.

3. A dual purpose electron stream focusing and electromagnetic wave retarding circuit including a plurality of longitudinally spaced wire-like conductors surrounding an axis, said conductors being interwound in helical fashion to form a multifilar helix along said axis, each of said conductors being so wound as to form a helix having a first portion having a noncircular cross-sectional configuration and a second portion having a cross-sectional configuration similar to and rotated with respect to said first configuration of said first portion, said portions alternately occurring along the length thereof, the alternations in configuration of the several helices so formed occurring simultaneously along the length of said multifilar helix and angularly rotated with respect to each other, and direct potential means connected to said plurality of conductors for producing an electrostatic focusing field in the region surrounded by said conductors.

4. A dual purpose electron stream focusing and electromagnetic wave retarding circuit as claimed in claim 3 wherein the number of conductors is two and the angular rotation of the configurations is 90 degrees.

5. In combination, means for forming and projecting an electron stream, a source of direct voltage, and first and second interwound wave transmission helices surrounding said electron stream, each helix having a succession of sections along the length thereof, each section having a plurality of turns, each turn comprising at least a pair of diametrically opposed portions which are closer to the helix axis than the portions of said turn intermediate said diametrically opposed portions, the said opposed portions in adjacent sections of each helix being angularly rotated relative to each other and the diametrically opposed portions in the turns of said second helix being angularly rotated relative to corresponding portions in said first helix, said helices being connected to different terminals in said source of direct voltage.

6. The combination of elements as in claim 5 wherein the diametrically opposed portions in adjacent sections of each of said helices are rotated 90 degrees with respect to each other, and the diametrically opposed portions in the turns of said second helix are angularly rotated 90 degrees with respect to corresponding portions in said first helix, and the two helices are connected to opposite poles of said source.

References Cited in the file of this patent

UNITED STATES PATENTS

2,064,469	Haefl	Dec. 15, 1936
2,103,645	Schlesinger	Dec. 28, 1937
2,110,553	Knoll	Mar. 8, 1938
2,183,398	Hehlgans	Dec. 12, 1939
2,725,499	Field	Nov. 29, 1955