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TRAVELING WAVE TUBE

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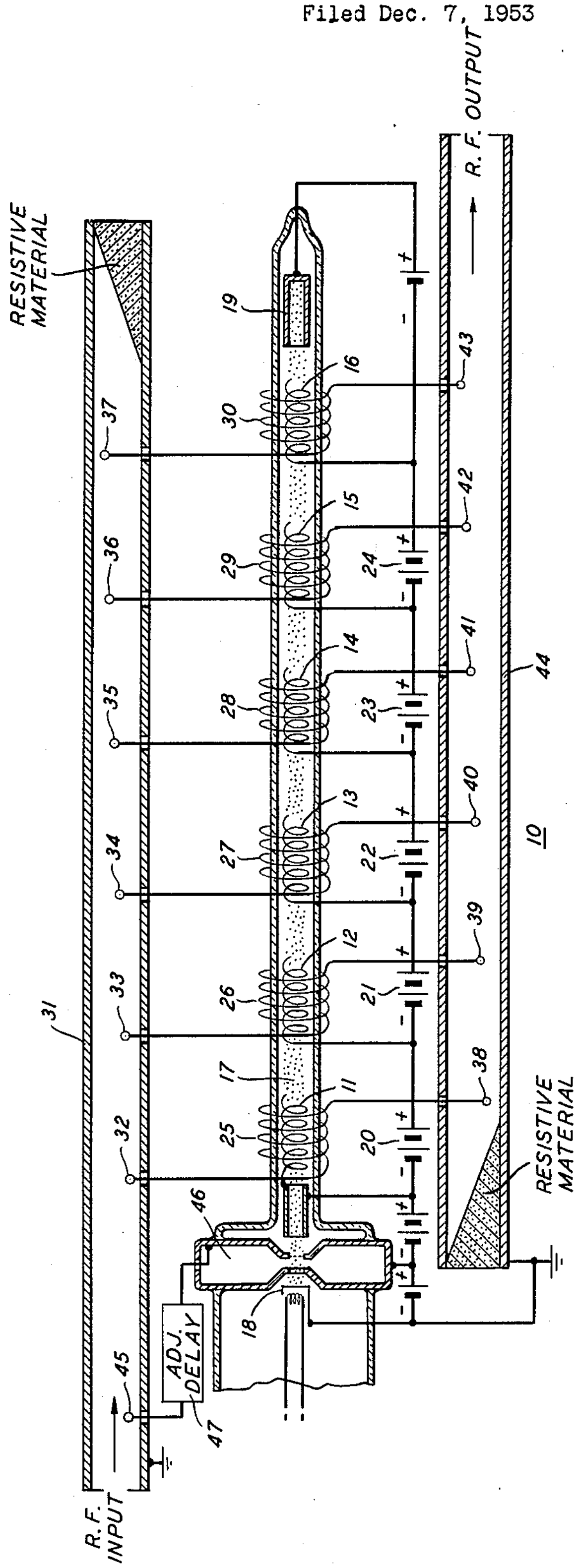

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TRAVELING WAVE TUBE

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8 Claims. (Cl. 179—171)

This invention relates to devices utilizing electron beams and more particularly to traveling wave tubes.

An object of this invention is to improve the efficiency of traveling wave tubes.

Traveling wave tube amplification of wave energy makes use of the interaction which results between an electron stream and the electric field of a traveling or propagating electromagnetic wave when the electron stream is beamed in coupling relation to the wave electric field. When the electron stream is properly synchronized with the traveling wave, some of the kinetic energy of the electrons is transformed into electromagnetic energy. The electrons, as a result of this transformation, are slowed down in proportion to the energy extracted from them. As the average velocity of the electrons decreases, however, they fall more and more out of synchronism with the traveling wave until finally no useful exchange of energy is possible. To compensate for the nonuniformity in the average velocity of the electrons, it has been suggested that in a conventional helical traveling wave tube the pitch of the propagating helix be made to vary from greater to smaller down the length of the electron stream. In this manner the axial velocity of the traveling wave can be slowed down in proportion to the slowing down of the electrons. This arrangement unfortunately suffers from the disadvantages that the pitch taper for efficient operation is a function of, among other parameters, steady state beam current. Accordingly, for a given physical helix structure of this type, there is only one value of beam current and one value of radio frequency power level within a very narrow range, which can be used efficiently. Other beam currents and other power levels require different helix tapers. As a result, the versatility or flexibility of operation of this kind of tube is undesirably limited. The present invention seeks to provide a traveling wave tube which approaches, although it does not achieve, 100 per cent efficiency, and which is not limited to operation with a single-valued beam current and single radio frequency power level. As will appear, one of the advantages of the invention is that the tendency of the electrons to fall out of synchronism with the traveling wave field can easily be compensated for electrically rather than in the mechanical way suggested previously and outlined above.

In accordance with the present invention, in one specific embodiment thereof, a number of slow wave circuits such as wire wound helices are positioned in succession along and surrounding the path of an electron stream. As the electrons pass through each successive circuit they give up energy to the radio frequency field in this region and as a result their average velocity is decreased. Each circuit is maintained at a higher direct potential than that of the preceding circuit so that the electrons when passing from the electrostatic field of one circuit to that of the next are accelerated by an amount corresponding to the potential difference between the two circuits. Thus the average velocity of the electrons can be maintained within certain limits even though a large amount of kinetic energy is being extracted from them. A very advantageous arrangement is provided in conjunction with these successive circuits for supplying to them radio frequency signals in the proper phases. The arrangement is an improvement over that disclosed in a copending application Serial No. 396,437 filed by R. Kompfner on the same date as the present application.

A more complete understanding of the invention, together with a better appreciation of its advantages will best be gained from a study of the following detailed description given in connection with the accompanying drawing in which the single figure shows in schematic form a traveling wave tube employing successive electron stream signal wave interaction circuits.

Referring now particularly to the drawing, the figure shows an illustrative embodiment of a traveling wave tube **10** made in accordance with the invention. In this embodiment electrons are beamed by any convenient means along an axis enclosed within an evacuated envelope of suitable dimensions. The electrons can be confined to the axis of flow by any convenient means such as a longitudinal magnetic field aligned parallel to the axis. For purposes of simplicity, however, no such means has been shown in the drawing. As the electrons travel along the axis of flow they are acted upon by successive electromagnetic fields maintained around the electron stream by appropriate means. Here these means include helices **11**, **12**, **13**, **14**, **15**, and **16** placed around electron stream **17** at points successively along its path from electron gun **18** to collector anode **19**. Each of these helices is maintained at potentials successively higher than the potential of cathode or gun **18**. That is, helix **11** is maintained at a potential higher than that of electron gun **18**, but lower than the potential of helix **12**, and each succeeding helix along the length of the tube from gun **18** to collector **19** is maintained at a higher electrical potential than its preceding helix closer to the gun **18**. In this embodiment these potentials are supplied by sources **20**, **21**, **22**, **23**, and **24** connected to helices **11** through **16** as shown. While the voltages provided by these sources may be equal to each other it should be understood that they may be adjusted separately to any desired value when it is convenient to do so. Surrounding each of helices **11** through **16** is a respective one of helices **25** through **30**. By means of these outer helices radio frequency signals can be impressed in turn upon the inner helices and the electron stream. A radio frequency input signal circuit consisting of hollow wave guide **31** is connected at appropriate points along it to each of helices **25** through **30** by means of probes **32** through **37**. The spacings along the guide between successive probes are made so that the phases of the voltages applied to helices **25** through **30** have the proper relationship to each other and to the phase of the signal propagating along the electron stream. The amount of the voltage applied to a helix can conveniently be varied by adjusting the depth of penetration into the guide **31** of the probe connected to the helix. In this manner the efficiency of operation of tube **10** can be maximized by avoiding overbunching of the electron stream. The output ends of helices **25** through **30** are connected in a way similar to the input connections by means of probes **38** through **43** inserted in hollow wave guide **44**.

The lengths of helices **25** through **30** and their respective inner helices **11** through **16** should each be substantially one-half the beat wavelength, that is, the wavelength of the standing wave which would appear on a uniform transmission line made up of concentric helices such as **11** and **25**. The pitches of the two helices comprising the inner and outer helices of each pair should be approximately the same in magnitude but in opposite sense. Under these conditions, wave energy applied to the left or upstream end of an outer helix such as helix **25** will be almost entirely transferred onto the inner helix such as helix **11** before it reaches the end of the outer helix. Thus, both the input and output ends of the outer helices will be located at voltage antinodes and the ends of the inner helices will be located at voltage nodes. Throughout the specification the term "upstream" is used to denote a point or location closer to the electron gun than the point or location with which it is being compared. Conversely, the term "downstream" denotes a point or location closer to the collector than the point with which it is being compared. The beat wavelength is most easily determined by measurement although it can be determined in the way disclosed in copending application of R. Kompfner, Serial No. 355,028, filed May 14, 1953.

For efficient operation of tube **10**, the depth of probe **45** into guide **31** should be varied until the proper bunching voltage is applied to electron stream **17** via bunching cavity **46**. Sources **20** through **24** may also be adjusted individually to insure that the electrons are in proper synchronism with the electric fields traveling down the various helices. The pitch of these helices, of course, determines the velocity at which these fields travel which should be approximately equal to the velocity of the electron stream.

As the electrons travel along the path of stream **17**, which is congruent with the common axis of the successive helices, they first come to the region surrounded by any suitable electron stream bunching means such as the cavity **46** which is shown or a short helix similar to helix **11** in which some of the electrons are retarded and others are accelerated in accordance with the variations in intensity of the signal wave propagating along the helix. By this action the electrons are bunched into groups which proceed down the tube, being timed by means of adjustable delay **47** and the gap between buncher **46** and helix **11**, to reach the region surrounded by helix **11** at the proper instant to be retarded by the signal wave propagating along the helix. The tube circuit parameters are arranged so that while within this region the electrons are decelerated by an amount corresponding to the voltage supplied by battery **20**. The number of times the electrons are accelerated and decelerated in this way as they travel to the anode **19** determines the total amount of energy which can be extracted from them and consequently the amount of wave amplification obtainable.

The degree of bunching of the electron stream produced by buncher **46** is a factor determining the efficiency of tube **10**. As the bunching becomes more perfect the efficiency increases and this effect makes tube **10** useful as a high level expander, that is, an amplifier whose gain increases as the signal level increases.

Helices **11** through **16** provide a desirable way of impressing radio frequency signal voltages on electron stream **17** because they can be connected, without additional radio frequency insulating elements, directly to batteries **20** through **24**. If desired, however, these helices can be replaced by appropriate accelerating grids.

The foregoing explanation is intended in illustration and not in limitation of the principles of the invention. Various changes or modifications in the embodiment illustrated may occur to those skilled in the art and these changes may be made without departing from the spirit or scope of the invention as set forth. In particular, instead of helical wave propagating circuits such as those shown, various other wave propagating circuits may be used. Moreover, the number of circuits to be used is not limited to the six shown but may be greater or smaller depending upon the tube efficiency required. In general, the larger this number, the greater the efficiency.

What is claimed is:

1. In an electronic device, means for forming and projecting an electron stream, means for bunching said stream in accordance with a signal, a plurality of means located along said stream in field coupling relation thereto for causing interaction between said stream and a single electromagnetic wave signal, means for maintaining the average velocities of the electron stream at successive points along it approximately equal to each other, extended input wave guiding means to which said bunching means and said plurality of means located along said stream are connected respectively at successive points of proper phase relation along the wave guiding means, and an extended output wave guiding means to which said plurality of means located along said stream are connected respectively at successive points of proper phase relation therealong.

2. The combination of elements of claim 1 in which said input and output wave guiding means are conductively bounded wave guides.

3. The combination of elements of claim 1 in which each of said plurality of means located along said stream is a pair of concentric coupled helices surrounding the electron stream.

4. The combination of elements of claim 1 in which said means for maintaining the average velocities of the electron stream are a plurality of direct current voltage sources.

5. The combination of elements of claim 1 in which said plurality of means located along said stream include parallel connected helices of equal pitches.

6. In a device which utilizes the interaction between an electron beam and an electromagnetic wave to amplify the wave, means for forming an electron beam and for projecting said beam along a predetermined path, means for bunching the electrons of said beam in accordance with a signal, a plurality of separate interaction circuits arranged in spaced succession along the beam paths for propagating electromagnetic wave energy in coupling proximity with said electron beam, said succession extending along the beam path a distance of several wavelengths and characterized in that each of the interaction circuits has substantially the same phase velocity propagating characteristics, means for maintaining the average velocity of the electron beam substantially the same at the upstream end of each of the successive interaction circuits along the beam path, an extended input wave guiding means to which said bunching means and said plurality of interaction circuits are connected respectively at successive points of proper phase relation along the wave guiding means, and an extended output wave guiding means to which said plurality of interaction circuits located along said beam path are connected respectively at successive points of proper phase relation therealong.

7. In a device which utilizes the interaction between an electron beam and an electromagnetic wave to amplify the wave, means for forming an electron beam and for projecting said beam along a predetermined path, means for bunching the electrons of said beam in accordance with a signal, a plurality of separate interaction circuits arranged in spaced succession along the beam paths for propagating electromagnetic wave energy in coupling proximity with said electron beam, said succession extending along the beam path a distance of several wavelengths and characterized in that each of its interaction circuits has substantially the same phase velocity propagating characteristics, means for maintaining each interaction circuit of the succesion at a higher D.-C. potential than the adjacent interaction circuit which is upstream thereof, an extended input wave guiding means to which said bunching means and said plurality of interaction circuits are connected respectively at successive points of proper phase relation along the wave guiding means, and an extended output wave guiding means to which said plurality of interaction circuits located along said beam path are connected respectively at successive points of proper phase relation therealong.

8. In a device which utilizes the interaction between an

electron beam and an electromagnetic wave to amplify the wave, means for forming an electron beam and for projecting said beam along a predetermined path, means located along said path for bunching said electron beam in accordance with a signal, a plurality of pairs of helices spaced downstream from said bunching means and arranged in spaced succession over a distance of several operating wavelengths along the beam path for propagating electromagnetic wave energy in coupling relation with said beam, the two helices of each pair having unequal radii and being positioned coaxially and substantially coextensively along a portion of the electron beam for forming a concentric pair having inner and outer helices, the pitch of the inner and outer helices of each of the concentric pairs being equal and of opposite sense, means for maintaining one helix of each

of the different concentric pairs at a different D.-C. potential, a first conductively bounded wave guide serving as an input wave guiding means to which said bunching means and said plurality of pairs of helices are connected respectively at successive points of proper phase relation, along the wave guide, and a second conductively bounded wave guide serving as an output wave guiding means to which said plurality of pairs of helices are connected respectively at successive points of proper phase relation therealong.

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