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TRAVELING WAVE TUBE HAVING MEANS FOR REMOVING SLOW
ELECTRONS FROM ELECTRON BEAM
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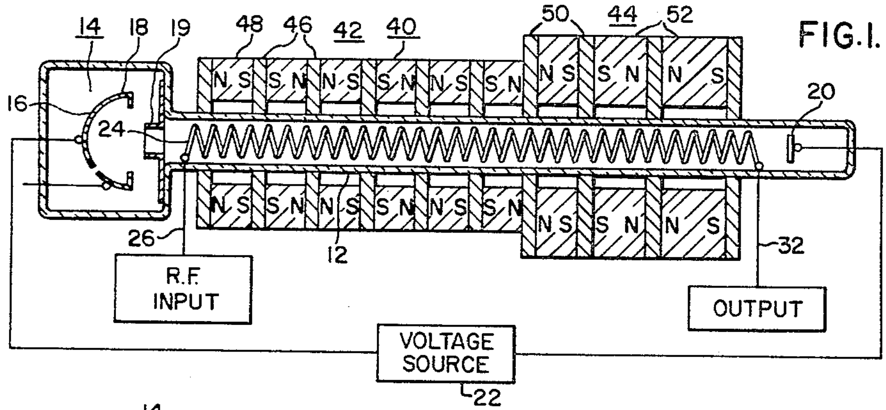

FIG.1.

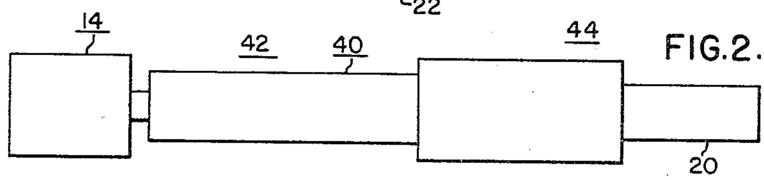

FIG.2.

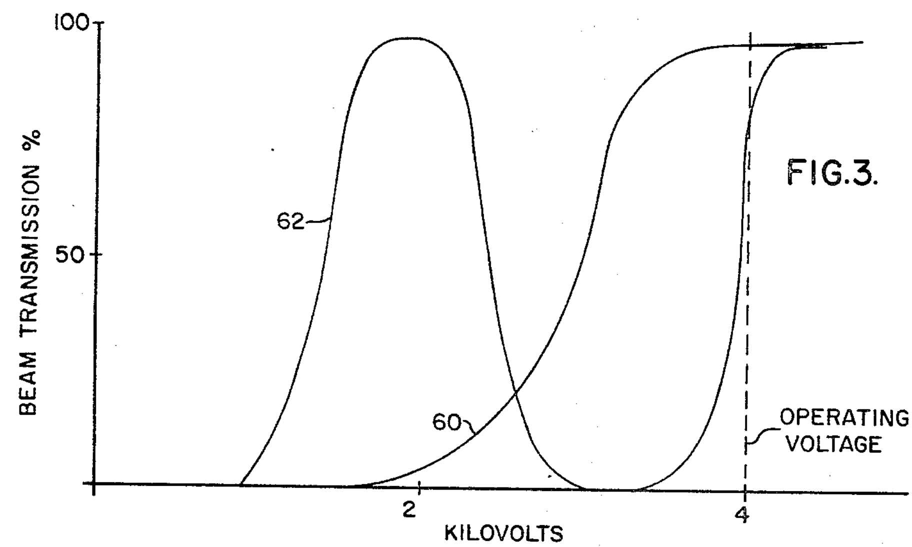

FIG.3.

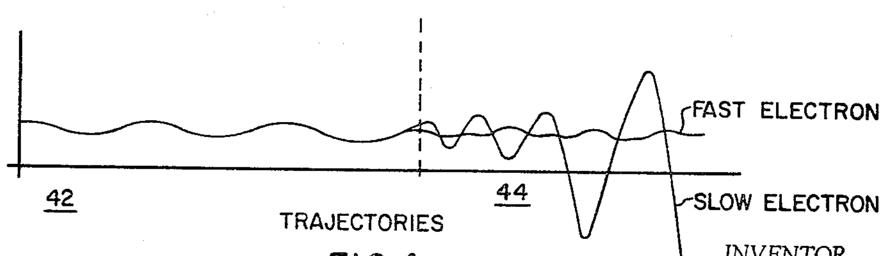

FIG.4.

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TRAVELING WAVE TUBE HAVING MEANS FOR REMOVING SLOW ELECTRONS FROM ELECTRON BEAM

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ABSTRACT OF THE DISCLOSURE

This invention relates to a traveling wave tube system in which periodic magnetic focusing is utilized and in which the low energy electrons which extract energy from the sole wave structure are removed from the electron beam by utilization of a period magnetic focusing arrangement operating within selected pass bands and/or selected portions of said pass bands of said periodic magnetic focusing system.

This invention relates to traveling wave tubes and more particularly to those tubes utilizing periodic focusing.

In a traveling wave tube, an electron beam is projected along an interaction circuit along which a signal wave is propagating. When the signal wave on the interaction slow wave structure is propagating in a manner such that there is a component of electric field of the wave which is parallel to the beam, interaction occurs between the beam and the signal wave. Such interaction takes the form both of extraction of energy from the electron beam by the signal wave and in the extraction of energy from the signal wave by the beam. The interaction, in which the beam extracts energy from the signal wave, decreases the efficiency of the device. To improve efficiency, it has been proposed to decrease the pitch of the slow wave structure near the output end and thereby decrease the phase velocity of the signal wave to match the decreased velocity of the electrons near the output end of the slow wave structure. Other methods and techniques have been utilized in an attempt to remove the low velocity electrons which extract energy from the signal wave propagated along the slow wave structure. The removal of these slow electrons must be accomplished without disturbing the flow of the other electrons in the stream which are still delivering energy to the slow wave structure.

Periodic magnetic focusing is capable of defocusing the slow electrons while passing fast electrons which still have available energy for transfer to the circuit wave, when the periodicity of the magnetic field, the voltage, the current in the beam, and the diameter of the electron stream are chosen properly. The defocused slow electrons can be collected on the slow wave structure and the remaining electrons in the beam consist of only those electrons which deliver energy to the slow wave structure.

Unlike the case of a uniform magnetic field, the periodic focusing field is not necessarily improved by increasing the magnetic field strength beyond a given value. Instead there are encountered regions of magnetic field strength which caused the beam to diverge or defocus. For a given magnetic field strength, the velocity of an electron within the beam determines whether the particular electron is focused or defocused. Defocused electrons, if the defocusing is sufficient may be removed from the electron beam. This difference in behavior of electrons within the electron beam under the influence of a periodic magnetic field gives rise to regions of good transmission or pass bands wherein for a given magnetic field a range of velocities of electrons will be focused and regions of poor transmission or stop bands where with the same magnetic field there is a range of velocities where the electrons will be defocused.

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It is, accordingly, an object of this invention to provide an improved traveling wave tube system.

It is another object to improve the efficiency of traveling wave tubes by removing undesirable electrons from the electron beam and thereby improve the efficiency of the device.

It is another object of the invention to provide a traveling wave tube system in which periodic magnetic focusing is provided and velocity selection of electrons in the beam is accomplished.

Briefly, the present invention accomplishes the above objects by providing a traveling wave tube system in which periodic magnetic focusing is provided and in which slow electrons which extract energy from the slow wave structure are removed from the electron beam by utilization of a periodic magnetic focusing arrangement operating within the second pass band.

Further objects and advantages of the invention will become apparent as the following description proceeds, and features of novelty which characterize the invention will be pointed out particularly in the claims annexed to and forming a part of this specification.

For a better understanding of the invention, reference may be had to the accompanying drawings, in which:

FIGURE 1 is a sectional view of a traveling wave tube incorporating the teaching of this invention;

FIG. 2 illustrates the traveling wave tube of FIG. 1 in block form incorporating the teaching of this invention;

FIG. 3 illustrates a plot of transmission current versus voltage with a fixed magnetic field and a fixed beam current in a periodic magnetic focusing system; and

FIG. 4 illustrates the effect of the periodic magnetic focusing systems within the traveling wave tube of FIG. 1.

Referring to FIG. 1, reference numeral **10** designates a traveling wave tube comprising a conventional envelope **12** which may be of a suitable material such as glass. The envelope **12** is provided with an electron gun **14** at one end of the envelope and includes at least a cathode **16**, a focusing electrode **18** and an anode **19** for forming and focusing the electron beam generated by the cathode **16**. A target or a collector electrode **20** is positioned at the opposite end of the envelope **12** for collecting the electrons generated by the electron gun **14**. The collector **20** is maintained at a suitable potential positive with respect to the cathode **16** by means of suitable lead-in connections from a voltage source **22**. The electrodes are shown diagrammatically in that the details are well known and any suitable structure may be utilized.

Interposed between the electron gun **14** and the collector **20** is a suitable slow wave interaction circuit illustrated as a helical coil conductor **24**. The slow wave circuit **24** may be of any suitable type. The slow wave assembly **24** may also serve as an accelerating electrode for the electron beam and may be maintained at a suitable positive potential with respect to the cathode **16** of the electron gun **14**.

At each end of the slow wave structure **24**, coupling is provided to external transmission lines by any suitable means. In the specific embodiment shown, the input signal is applied to the helix **24** by a lead-in **26**.

At the output end of the slow wave structure **24**, there is provided an output coupling means **32**. In the specific embodiment shown, the output coupling means **32** is a lead-in connected to the helix **24** and energy is transferred for utilization from the helix **24** to an output. It is obvious that a number of different types of devices may be utilized for coupling to the slow wave structure **24**.

Disposed along the path of the flow of the electron beam from the cathode **16** to the collector **20** is a periodic magnetic focusing system **40**. In the spectific embodiment shown, the periodic focusing system **40** consists of a first portion or input section **42** and a second portion or velocity selection section **44**. The first periodic magnetic focusing section **42** consists of uniformly spaced annular pole pieces **46** of a material having a high magnetic permeability such as soft iron, a series of ring-shaped magnets **48** are disposed across successive gaps between the pole pieces **46**. The magnets **48** are magnetized axially and arranged coaxially so that adjacent magnets exert oppositely directed magnetic fields. This provides along the path of the electron flow a succession of regions of longitudinal magnetic fields, the direction of the magnetic fields reversing with each successive region. The design of the periodic magnetic focusing section **42** is such as to provide transmission, as illustrated by curve **60** in FIG. 3. The design of the section is such that the majority of the electrons within the electron beam entering the slow wave structure **24** are transmitted through the section **42** and focused within the first band pass region illustrated in FIGS. 3 and 4. The section **42** operates in the first pass band region.

The periodic magnetic focusing section **44** provides transmission as illustrated by curve **62** in FIG. 3. FIG. 4 illustrates the action of section **44** on the electrons. The strength of the magnetic field in section **44** is different from that of section **42** so as to alter the stop and pass band arrangements with regard to velocity of the electrons in the beam as illustrated in FIGS. 3 and 4. In the specific embodiment shown the magnetic field in section **44** is such as to pass the majority of the electrons in the beam which are in the second pass band region and selected so that the focusing structure operates on the low voltage end of the second pass band. The focusing arrangement **44** includes spaced annular pole pieces **50** of similar material as pole pieces **46**. A series of substantially axially magnetized ring magnets **52** are disposed along successive gaps between the pole pieces **50**. The magnets **52** across adjacent gaps are arranged to exert oppositely directed magnetic fields whereby successive regions of longitudinal magnetic fields are provided in which the direction of the magnetic fields reverse with each successive region. The last few periods or regions of the focusing arrangement **44** are slightly increased in peak magnetic field by increasing the thickness of the magnets **52**. The period of section **44** is longer than the period of section **42**.

In the operation of the device in FIG. 1, the electron beam generated by the electron gun **14** is projected along the axis of the envelope **12**. The electrons leaving the electron gun **14** are of substantially uniform velocity. Upon interaction with the slow wave circuit **24**, the velocity of the electrons is spread due to the interaction with the circuit. The first focusing section **42** is designed to operate in the first pass band and acts on the majority of the electrons within the electron beam. Any electrons that have velocities not in the first pass band shown in FIG. 3 of course will be defocused and collected by the slow wave structure **24**. The electrons upon entering the second focusing region **44** now have a considerable spread of velocity due to the long interaction with the slow wave circuit **24** through the section **42** and a more considerable spread of electron velocities is found within the electron beam. The second focusing region **44** is designed to work on the lower edge of the second pass band illustrated in FIG. 3 and therefore the electrons having a low velocity will be defocused within the stop band located between the first and second pass bands and be collected on the slow wave structure **24**. The second focusing system **44** is designed so that the lower edge of the second pass band is located so that substantially all of the undesirable low velocity electrons are defocused and all of the desirable high velocity electrons are focused and passed through the structure within the second pass band region. The velocity selection provided by the lower edge of the second pass band is particularly desirable in that the pass band edge can be made sharp. A 5 or 10 percent change in velocity

can result in a change in beam transmission from about 90 percent to nearly zero percent. This lower edge of the second pass band provides a very high selectivity. Another desirable feature of this device is that there is no sharp transition in focusing and the low velocity electrons are defocused over a relatively long length of the slow wave structure.

The last few periods of section **44** can be altered by increasing special periodicity or by increasing the peak magnetic fields. The latter is especially attractive since it would provide better focusing for the fast electrons due to the RF beam break-up.

While there have been shown and described what are at present considered to be the preferred embodiment of the invention, modifications thereto will readily occur to those skilled in the art. For example, it is apparent that although the device has been described with more than one periodic focusing arrangement, any focusing arrangement may be utilized as long as at least a portion of the structure includes velocity selection by use of the lower edge region of the second pass band. For instance, periodic electrostatic focusing or periodic quadrupolar magnetic focusing schemes could be employed. Also, within the scope of this invention is adjustment of the lower edge of the second pass band of a PPM focusing system by varying the magnetic circuit geometry, the strength of the magnets, the magnetic material, or any combination of the above. It is not desired, therefore, that the invention be limited to the specific arrangements shown and described, and it is intended to cover in the appended claims all such modifications as fall within the true spirit and scope of the invention.

I claim as my invention:

1. A traveling wave tube comprising a slow wave circuit, an electron beam source and collector for forming and projecting an electron beam along said slow wave circuit in coupling relation thereto, a signal input means and a signal output means spaced apart along said slow wave circuit, a first periodic focusing means disposed along a portion of said slow wave circuit between said input and said output coupling means and having a first velocity pass band and a velocity stop band of lower velocity than said pass band for establishing a first focusing region for electrons within said electron beam wherein the velocity of the majority of the electrons in said beam fall within said velocity pass band and a second periodic focusing means disposed along a second portion of said slow wave circuit between said first focusing means and said output means having a first and second velocity pass band and a velocity stop band therebetween for establishing a second focusing region wherein the velocity of the electrons within said beam capable of delivering energy to said slow wave circuit fall substantially within said second velocity pass band and near the lower edge region of said second velocity pass band so that electrons having velocities such as to extract energy from said slow wave circuit fall within said velocity stop band of said periodic focusing means and are defocused from the electron beam.

2. A traveling wave tube comprising a slow wave circuit, an electron beam source and collector for forming and projecting an electron beam along said slow wave circuit in coupling relation thereto, a signal input means and a signal output means spaced apart along said slow wave circuit, a first periodic focusing means disposed along a portion of said slow wave circuit between said input and said output coupling means and having a velocity pass band and a velocity stop band of lower velocity than said pass band for establishing a first focusing region for electrons within said electron beam wherein the velocity of the majority of the electrons in said beam fall within said velocity pass band and a second periodic focusing means disposed along a second portion of said slow wave circuit between said first focusing means and said output means having a first and second velocity pass band and a velocity stop band therebetween for establishing a second focusing region wherein the velocity of the electrons within said beam capable of delivering energy to said slow wave circuit fall substantially within said second velocity pass band and near the lower edge region of said second velocity pass band and electrons having velocities such as to extract energy from said slow wave circuit fall within said velocity stop band of said second periodic focusing means and are defocused from the electron beam and collected by said slow wave structure.

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