Jan. 10, 1956 A. LERBS 2,730,648

TRAVELLING-WAVE TUBE

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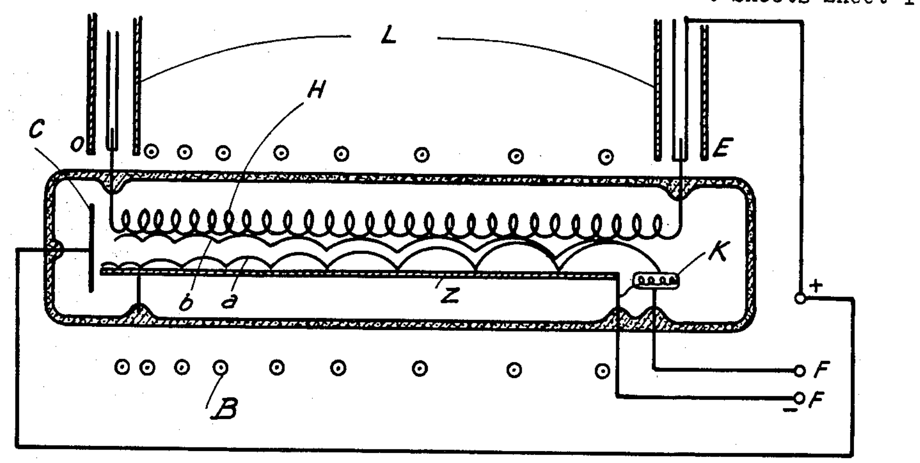

Fig. 1a

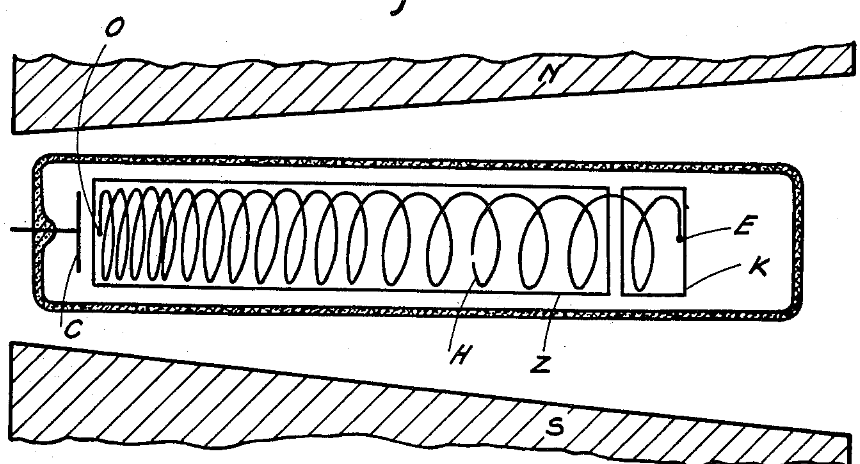

Fig. 1b

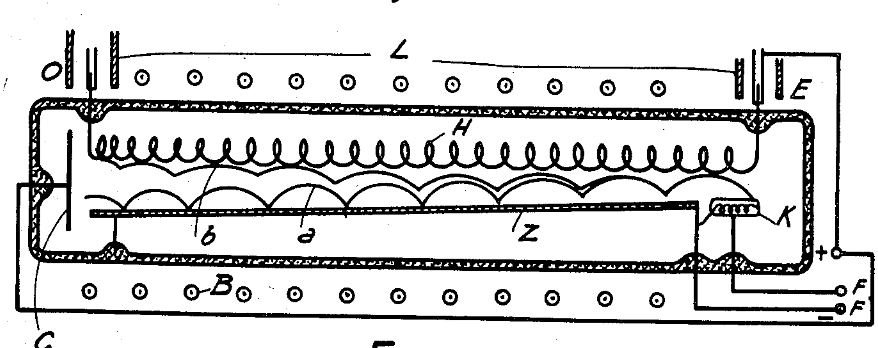

Fig. 2a

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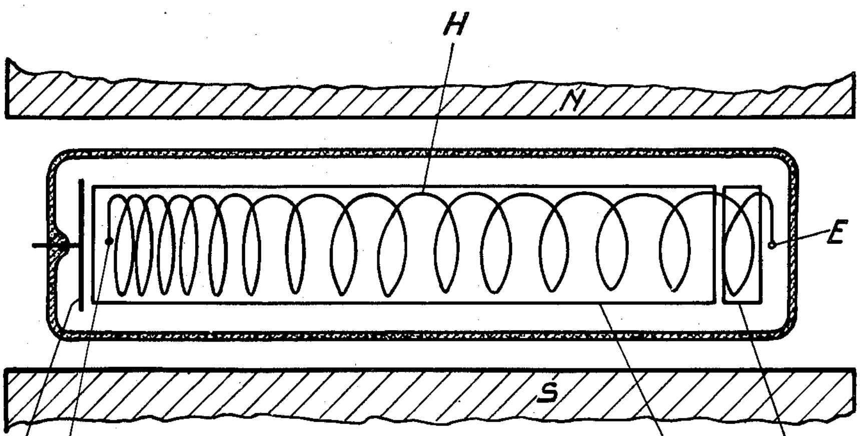

Fig. 2b

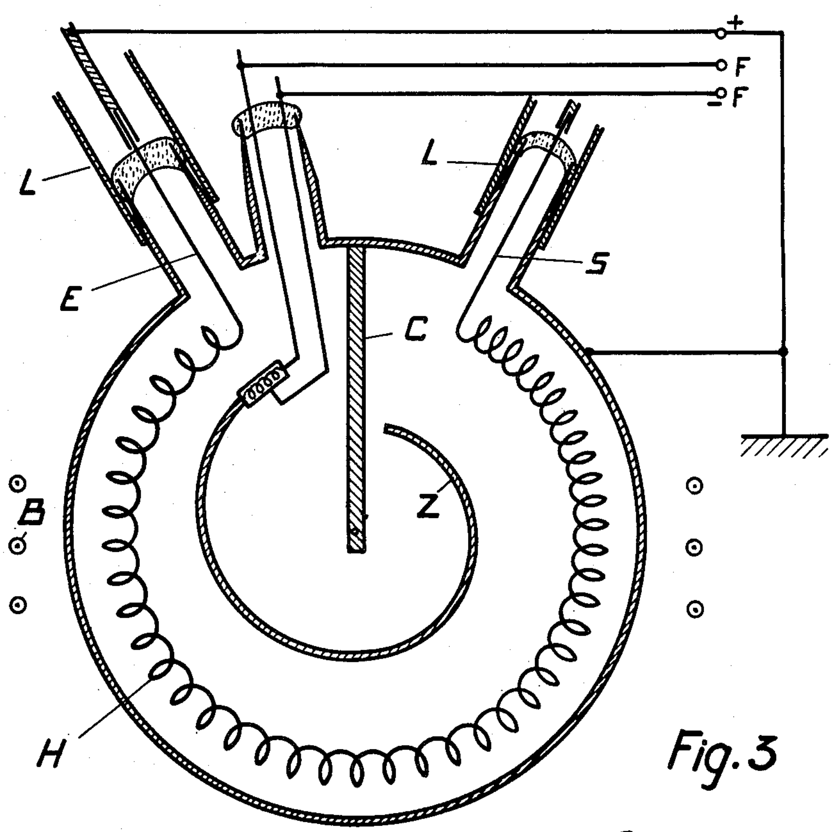

Fig. 3

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TRAVELLING-WAVE TUBE

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Claims priority, application France February 4, 1949

7 Claims. (Cl. 315—3.5)

My invention relates to travelling-wave tubes provided with a transverse magnetic field, and its object is to obtain simultaneously a high efficiency and a high amplification in such tubes.

It is known that a tube of the type in question has a retardation line, of the shape of a helix for example, which is raised to a positive potential with respect to another electrode extending in a parallel direction. An electron beam emitted by a cathode is introduced into the space between these two electrodes at a speed which is substantially equal to the speed of propagation of an electromagnetic wave in the retardation line, and a magnetic field is applied transversely to the directions of the beam and the electrostatic field.

In the known constructions of this type of tube, the magnetic field is constant all along the retardation line, and the distance between the two electrodes is also constant.

This arrangement has the drawback that the optinum conditions of anode voltage and of the magnetic field are not identical for the gain and for the efficiency, since the electrodes describe cycloidal trajectories in the space between the electrodes and the induction of the magnetic field B passes through a critical value B_{cr} at the instant when said trajectories begin to touch the retardation line. It is known that a high gain requires the ratio

$$\frac{B}{B_{cr}}$$

to be nearly equal to 1, whereas the efficiency increases more and more as

$$\frac{B}{B_{cr}}$$

becomes greater than 1.

My invention makes it possible to combine a high gain with a high efficiency, by making

$$\frac{B}{B_{cr}}$$

variable along the retardation line.

It is thus possible to choose at the input end of the retardation line a value of B such that

$$\frac{B}{B_{cr}}$$

is nearly equal to 1. The electrons thus pass very close to the retardation line and are located in a region in which the high-frequency field is as high in value as possible, thereby permitting of an efficient phase focusing. By advancing along the retardation line, the ratio

$$\frac{B}{B_{cr}}$$

can increase without impairing the amplification mechanism, since on the one hand the electrons are already focused at the beginning of the line, and on the other

hand under dynamic conditions they automatically move closer to the retardation line and transfer their energy to the high-frequency field which, moreover, has already increased owing to the amplification as it becomes more remote from the input end.

The ratio

$$\frac{B}{B_{cr}}$$

is given by the expression:

$$\frac{B}{B_{cr}}=\frac{B.d}{3.36\sqrt{V}}$$

in which d denotes the distance and V the voltage across the electrodes.

It can therefore be seen that this ratio can be varied either by increasing B or by increasing d, or by combining the variations of both these factors in a suitable manner. Consequently, in accordance with the present invention, it is essential that the product of the intensity of the magnetic field B and of the distance between the conductor and the retardation line, i. e. the distance d, increases from the input end to the output end of the retardation line, whereby the tube has a high gain in the first part of the propagation space adjacent to the input end and a high efficiency in the second part of the propagation space reaching to the output end of the tube.

Owing to the fact that the speed of the electrons, which can be expressed by:

$$v=\frac{V}{d.B}\,10^8 \text{ cm./sec.}$$

also varies with d or B, it is necessary to reduce the speed of the wave to that of the beam along the line, which can be effected as is known by acting on the pitch or the dimensions of the retardation line.

The invention will be better understood by considering the accompanying drawings in which:

Figs. 1*a* and 1*b* show an example of the application of the principle of the invention to a tube of straight shape, the application of said principle being effected by varying the magnetic induction;

Figs. 2*a* and 2*b* show an example of application to the same shape of tube by varying the distance between the electrodes, and

Fig. 3 shows an example of application to a tube of circular shape, also by varying the distance between the electrodes.

Fig. 1*a* shows a transverse section and Fig. 1*b* a sectional plan view of a first example of a tube to which the invention is applied. In these figures, H denotes the retardation line, for example of helical shape, provided with an input end E and an output end O which are coupled to the coaxial lines L. Z denotes the electrode which is parallel to H and which is raised to a negative potential with respect to the retardation line. K denotes the cathode and C the usual collector of the tube.

According to the invention the magnetic field B increases along the retardation line in the direction of the beam, by giving to the poles N and S, as shown in Fig. 1*b*, a shape which slopes towards the tube as the beam moves forwards. At the same time the helix H is given a pitch that progressively decreases in the direction of the beam, in order to decrease the speed of the wave as the speed of the beam decreases. The curve *a* represents the trajectory of an electron under static conditions and the curve *b* the trajectory of an electron of favorable phase, under dynamic conditions, which transfers energy to the high-frequency field. It can be seen that such an electron always remains in the region of high potential, that the amplitude of the cycloidal trajectory is very substantially equal, at the input end, to the distance between the electrodes, which favors efficient amplification, and that said amplitude decreases along the line, which favors a high efficiency.

In the modification of Figs. 2a and 2b, which show similar sections to Figs. 1a and 1b and in which the same reference letters denote identical members, the poles N and S, as shown in Fig. 2b, are parallel to the tube as in the usual systems, but in this case the electrode Z is no longer parallel to H but, as shown in Fig. 2a, gradually becomes more remote therefrom in the direction of the beam. The curve *b* shows that the same effect is obtained as in Fig. 1a, the curve *a* only differing from the corresponding curve of Fig. 1a by the invariable amplitude of the cycloid.

The efficiency in the cases of Figs. 1 and 2 is approximately the same, since it is given by the expression:

$$\eta=1-\left(\frac{B_{cr}}{B}\right)^2$$

and does not depend on the means by which the variation of

$$\frac{B}{B_{cr}}$$

is effected.

In order to obtain a high efficiency, the electrons must only reach the retardation line at a point which is as remote as possible from the input end, since in that case

$$\frac{B}{B_{cr}}$$

and the efficiency have higher values. In order to prevent the retardation line from collecting too great a quantity of electrons, which would lead to heat losses, the system must be so dimensioned that the electrons almost touch the retardation line near the output end and are collected after the output passage by a collector which can be readily cooled. This dimensioning can be easily effected in combination with the means proposed by the invention.

The invention can also be applied to a tube of circular shape. In this case, the solution involving a variable distance with a constant field is more favorable, since the production of a magnetic field that increases from the input end to the output end is rather difficult to obtain for the circular shape. Fig. 3, which uses the same reference letters as the previous figures, relates to this case. This figure does not require further explanation, since it only shows as a whole a travelling-wave tube of known circular shape provided with a transverse magnetic field, except that the inner electrode Z is bent into a spiral so as to become gradually more remote from the helix as the wave is propagated through the retardation line.

The invention is capable of being subjected to many modifications which do not alter its principle. Thus, the two solutions (variable field and variable distance) could be combined so as to obtain the most judicious law of variation of the ratio of the field to its critical value. In the variable field solution, the angle of inclination of the profile of the poles and the shape of said profile could be made suitable for correcting the distribution of the field and reducing it to any desired law. The principle of the invention does not depend on the shape of the tube or on the construction of the retardation line.

What I claim is:

1. In a travelling wave tube arrangement, in combination, an electron source emitting an electron beam along a predetermined path; a collector of electrons arranged spaced from said electron source in the path of said electron beam; a retardation line having an input end arranged in the region of said electron source and an output end arranged in the region of said collector of electrons, said retardation line extending along said predetermined path of said electron beam; means connected to said input end of said retardation line for exciting an electromagnetic wave therein; means connected to said output end of said retardation line for collecting the energy amplified by the electron beam; a conductor extending between said source and said collector and being spaced apart from said retardation line a distance of a predetermined magnitude so as to define therewith a space for the propagation of the electron beam emitted by said source; means for applying an electrostatic field between said retardation line and said conductor; and means for establishing a magnetic field having an intensity of predetermined magnitude in the space between said retardation line and said conductor at right angles to said electrostatic field and to the electron beam, one of said magnitudes gradually increasing from said input end to said output end of said retardation line, whereby the product of the intensity of said magnetic field and of said distance between said conductor and said retardation line gradually increases from said input end to said output end of said retardation line so that the tube has a high gain in the first part of the propagation space adjacent to said input end and a high efficiency in the second part of said propagation space adjacent to said output end.

2. In a travelling wave tube arrangement, in combination, an electron source emitting an electron beam along a predetermined path; a collector of electrons arranged spaced from said electron source in the path of said electron beam; a retardation line having an input end arranged in the region of said electron source and an output end arranged in the region of said collector of electrons, said retardation line extending along said predetermined path of said electron beam; means connected to said input end of said retardation line for exciting an electromagnetic wave therein; means connected to said output end of said retardation line for collecting the energy amplified by the electron beam; a conductor extending between said source and said collector and being spaced apart from said retardation line so as to limit therewith a space for the propagation of the electron beam emitted by said source; means for applying an electric field between said retardation line and said conductor; and means for establishing in the space between said retardation line and said conductor and at right angles to the electric field and to the electron beam, a magnetic field the magnitude of which gradually increases from said input end to said output end of said retardation line.

3. In a travelling wave tube arrangement, in combination, an electron source emitting an electron beam along a predetermined path; a collector of electrons arranged spaced from said electron source in the path of said electron beam; a retardation line having an input end arranged in the region of said collector of electrons, said retardation line extending along said predetermined path of said electron beam; means connected to said input end of said retardation line for exciting an electromagnetic wave therein; means connected to said output end of said retardation line for collecting the energy amplified by the electron beam; a conductor extending between said source and said collector and being spaced apart from said retardation line a constant distance so as to limit therewith a space for the propagation of the electron beam emitted by said source; means for applying an electric field between said retardation line and said conductor; and means for establishing in the space between said retardation line and said conductor and at right angles to the electric field and to the electron beam, a magnetic field the magnitude of which gradually increases from said input end to said output end of said retardation line, whereby the product of the intensity of said magnetic field and of said distance between said conductor and said retardation line gradually increases from said input end to said output end of said retardation line so that the tube has a high gain in the first part of the propagation space adjacent to said input end and a

high efficiency in the second part of said propagation space adjacent to said output end.

4. In a travelling wave tube arrangement, in combination, an electron source emitting an electron beam along a predetermined path; a collector of electrons arranged spaced from said electron source in the bath of said electron beam; a retardation line having an input end arranged in the region of said electron source and an output end arranged in the region of said collector of electrons, said retardation line extending along said predetermined path of said electron beam; means connected to said input end of said retardation line for exciting an electromagnetic wave therein; means connected to said output end of said retardation line for collecting the energy amplified by the electron beam; a conductor extending along substantially the entire length of said retardation line and spaced therefrom a distance gradually increasing from the input end to the output end of said retardation line, said conductor defining with said retardation line substantially along the entire length thereof a space of gradually increasing width for the propagation of the electron beam emitted by said source; means for applying an electrostatic field between said retardation line and said conductor; and means for establishing a magnetic field in the space between said retardation line and said conductor at right angles to the electrostatic field and to the electron beam.

5. In a travelling wave tube arrangement, in combination, an electron source emitting an electron beam along a predetermined path; a collector of electrons arranged spaced from said electron source in the path of said electron beam; a retardation line having an input end arranged in the region of said electron source and an output end arranged in the region of said collector of electrons, said retardation line extending along said predetermined path of said electron beam; means connected to said input end of said retardation line for exciting an electromagnetic wave therein; means connected to said output end of said retardation line for collecting the energy amplified by the electron beam; a conductor extending between said source and said collector and located along said retardation line spaced therefrom a distance gradually increasing from the input end to the output end

of said retardation line, so as to limit with said retardation line a space for the propagation of the electron beam emitted by said source; means for applying an electric field between said retardation line and said conductor; and means for establishing in the space between said retardation line and said conductor and at right angles to the electric field and to the electron beam, a magnetic field the magnitude of which gradually increases from said input end to said output end of said retardation line, whereby the product of the intensity of said magnetic field and of said distance between said conductor and said retardation line gradually increases from said input end to said output end of said retardation line so that the tube has a high gain in the first part of the propagation space adjacent to said input end and a high efficiency in the second part of said propagation space adjacent to said output end.

6. In a traveling wave tube arrangement according to claim 2, said means for establishing a magnetic field including two pole pieces arranged on opposite sides of said retardation line and forming between themselves a gap the width of which gradually decreases from said input end to said output end of said retardation line.

7. In a traveling wave tube arrangement according to claim 1, said retardation line consisting of a helix the pitch of which gradually decreases from said input end to said output end of said retardation line.

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