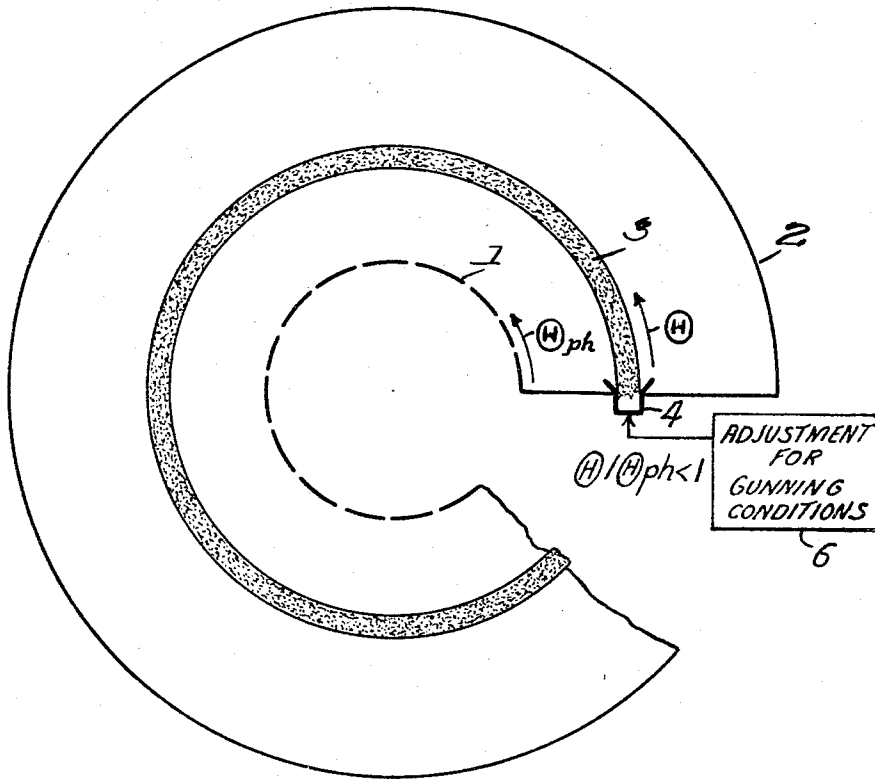
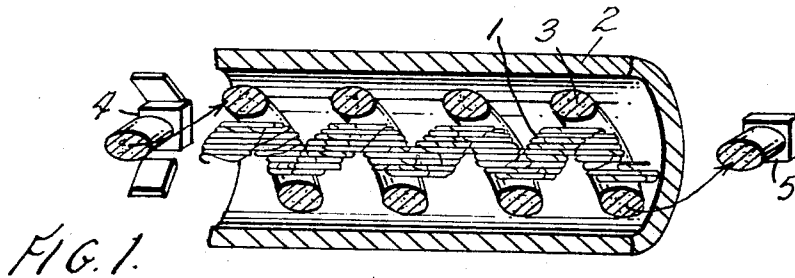


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TRAVELLING WAVE TUBE OPERATING WITH HELICALLY MOVING
ELECTROSTATICALLY GUIDED ELECTRON BEAM
Filed Oct. 24, 1963



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TRAVELLING WAVE TUBE OPERATING WITH HELICALLY MOVING ELECTROSTATICALLY GUIDED ELECTRON BEAM

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2 Claims. (Cl. 315—3.5)

The invention disclosed herein is concerned with a travelling wave tube, especially a high power tube, operating with an electron beam which is guided electrostatically along a helical path extending between an outer and an inner conductor, the inner conductor, which is with respect to the outer electrode acted on by a positive direct potential, being helically wound about the tube axis and operating as a delay line along which an electromagnetic wave is propagated with azimuthal delay following the electron beam motion.

There is a travelling wave tube known in which the electron beam is electrostatically guided along a helical path, in the space between a delay line and a cylindrical inner conductor which is with respect to the delay line acted on by a positive direct potential. The delay line extends helically about the cylindrical conductor which is cross-sectionally circular. The electrons moving along their paths are in reciprocal action with a wave guided along the delay line. The reciprocal action causes the electrons in known manner to give off energy to the high frequency field of the wave. A braking action is thus exerted on the electrons, with the consequence that the electrons reach the equilibrium paths with a smaller radius and that the spacing thereof from the delay line is increased. The coupling factor between the electron beam and the wave on the line decreases thereby steadily over the length of the discharge path. In order to avoid this disadvantage, it has been proposed, in connection with a travelling wave tube of the known kind, operating with an electron beam which is between an inner and an outer conductor electrostatically guided along a helical path, to form the inner conductor as a delay line.

In the proposed known travelling wave tube, the velocity of the electrons is so dimensioned that the angular velocity thereof is upon entering the helical path equal to or negligibly greater than the angular phase velocity of the wave along the delay line, which is coupled to the electron beam. The assumption underlying this dimensioning of the velocity was, that the electrons, upon reaching an equilibrium path with smaller radius by giving off kinetic energy to the high frequency field of the wave, retain their angular velocity. The synchronism which was originally present between the electrons and an electromagnetic wave propagated along the delay line, should in this manner be retained along the length of the discharge path, which is necessary for obtaining high efficiency of the tube.

It has now been found that the efficiency of tubes of this kind is lower than expected. The problem and object of the present invention therefore resides in discovering the reason for this phenomenon and eliminating it.

In order to achieve high efficiency in connection with a travelling wave tube of the initially noted type, it is according to the invention proposed to dimension the gunning conditions for the electron beam so that the electrons

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have, upon entering the helical path, an angular velocity which is by a few percent smaller than the angular phase velocity of the wave running along the delay line, which wave is coupled to the electron beam.

The invention is based upon the recognition of the surprising fact that the angular velocity of the electrons becomes upon transition from a path with greater radius to an equilibrium path with smaller radius, greater by the ratio of the radii. Accordingly, if synchronism between the electrons and the wave running along the delay line should already obtain upon entry of the electrons into the helical path, the electrons would, upon approaching the delay line due to the reciprocal action of the electrons with the wave, become ever faster and would thus come out of synchronism with the wave.

This drawback, which decreases the efficiency of the tube can be overcome by applying the gunning conditions according to the invention. The proof is obtained by a mathematical investigation, which results in the curved coordinate system of the tube, for the path of 16 electrons per high frequency period, in a system of 32 differential equations of second order, which are coupled over an integral term describing the giving off of energy. The numerical calculation has demonstrated that a degree of efficiency can be achieved, with appropriate selection of the spacing between the outer and the inner conductor as well as the potentials on these conductors, which comes close to the efficiency of known M-type tubes.

Important details of the invention will appear from the appended claims and from the description which is rendered below with reference to the accompanying drawing wherein:

FIGURE 1 is a side elevational view partly in section of the travelling wave tube constructed in accordance with the principles of the present invention; and

FIGURE 2 is a schematic end view of the travelling wave tube illustrated in FIGURE 1 and showing schematically the various structural elements thereof.

With reference to the drawings, the travelling wave tube of the present invention includes a delay line (inner conductor) 1 which is helically wound about the tube axis. Enclosing the delay line 1 is an outer conductor or electrode 2. An electron beam 3 is electrostatically guided along a helical path extending between the delay line 1 and the outer conductor 2 from an electron beam generating gun 4 to an electron collector 5.

The angular velocity of the electrons is indicated by ω and the phase velocity of the wave propagated along the delay line, which is coupled to the electron beam 3, is indicated by ω_{ph} . According to the present invention, there must be satisfied the requirement $\omega/\omega_{ph} < 1$. The angular velocity of the electrons is adjusted by means of an adjusting device 6 connected to the electron beam generating gun 4.

Changes may be made within the scope and spirit of the appended claims which define what is believed to be new and desired to have protected by Letters Patent.

I claim:

1. In the operation of a travelling wave tube operating with an electron beam which is guided electrostatically along a helical path extending between an inner and an outer conductor, wherein the inner conductor, which is with respect to the outer conductor acted on by direct potential, operates as a delay line which is helically wound about the tube axis and along which an electromagnetic wave is propagated with azimuthal delay, following the motion of the electron beam, the improvement therewith

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comprising means for coupling said electron beam to the electromagnetic wave travelling along said delay line and means for adjusting said coupling means to provide the electrons of said electron beam with an angular velocity which is less than the angular phase velocity of the wave propagated along the delay line, which wave is coupled to the electron beam, with the difference in such velocities being so selected that synchronism between the electrons and said wave is achieved only in the further course of the electron beam subsequent to such entry.

2. In the operation of a travelling wave tube, as defined in claim 1 wherein the electrons of said electron beam have an angular velocity ω upon entering the helical path of said electron beam which is related to the phase velocity v_{ph} of the electromagnetic wave propa-

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gated along the delay line and coupled to said electron beam so as to satisfy the requirement $\omega/v_{ph} < 1$.

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