

Nov. 30, 1954

D. REVERDIN
TRAVELING WAVE TUBE HAVING TRANSVERSE
MAGNETIC AND ELECTROSTATIC FIELDS

2,695,929

Filed March 22, 1952

2 Sheets-Sheet 1

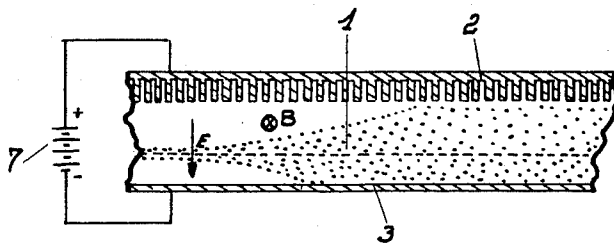


Fig. 1

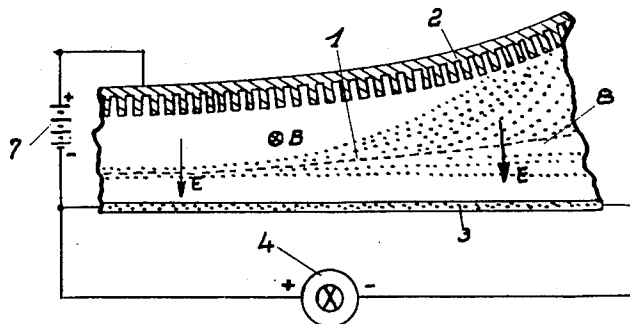


Fig. 2

INVENTOR
DANIEL REVERDIN
By *Haseltine, Lake & Co.*
AGENTS

Nov. 30, 1954

D. REVERDIN
TRAVELING WAVE TUBE HAVING TRANSVERSE
MAGNETIC AND ELECTROSTATIC FIELDS

2,695,929

Filed March 22, 1952

2 Sheets-Sheet 2

Fig. 3

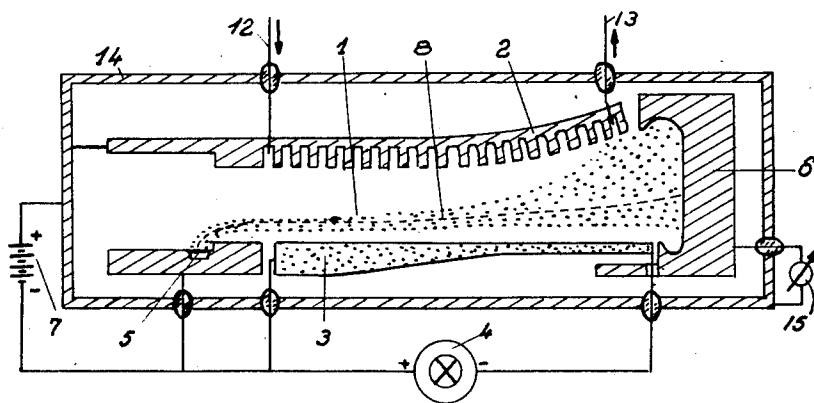
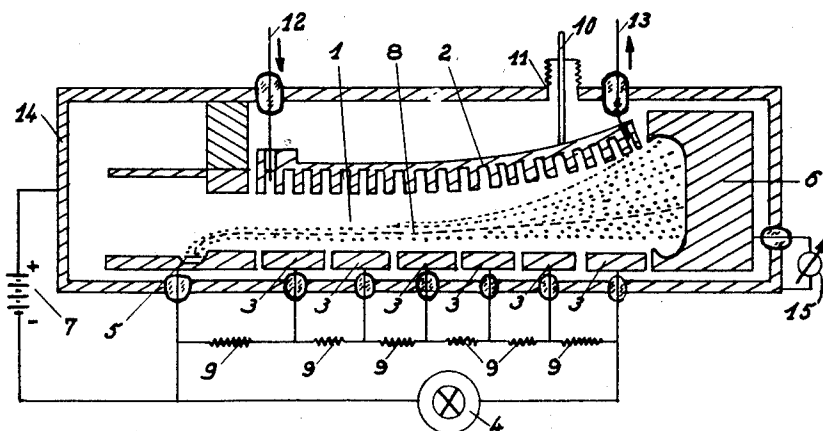


Fig. 4

INVENTOR
DANIEL REVERDIN
By *Hoseltine, Paker & Co.*
AGENTS

1

2,695,929

TRAVELLING WAVE TUBE HAVING TRANSVERSE MAGNETIC AND ELECTROSTATIC FIELDS

Daniel Reverdin, Paris, France, assignor to Compagnie Generale de Telegraphie Sans Fil, a corporation of France

Application March 22, 1952, Serial No. 277,940

Claims priority, application France March 29, 1951

5 Claims. (Cl. 179—171)

The present invention relates to travelling wave tubes of the type having a transverse magnetic field, and more particularly to means for improving the amplifying gain in tubes of this type.

Amplifying travelling wave tubes of the magnetron type are known which comprise an electron beam which is propagated in a direction perpendicular to the crossed magnetic and electric fields. The beam is in the shape of a flat ribbon and it is propagated between a delay anode and a cathodic electrode of plate form and at an average velocity equal to the phase velocity of the wave injected into the delay line incorporated in the anode.

The terms "width" and "thickness" used herein are synonymous and refer to the dimension of the beam in the direction from the cathodic electrode or plate to the anodic electrode or delay line.

Various guns have been designed for the production of that beam for which the thickness, and therefore the homogeneity of electron velocity, the average height above the cathodic electrode, and therefore the electronic efficiency, and the value of the total current are very important for the tube gain. Static tests have been performed for these various guns, and their static characteristics, that is to say, without any high frequency field, have been measured. In these tests, it has often been found that some beam electrons would reach the anode when the magnetic and electric field conditions were such that the beam electrons had not yielded the whole of their energy to the field, and hence, the energy conditions were not correct for the electrons reaching this electrode. This fact had been attributed to faulty focussing of the gun or to leakage of electrons past the edges of the interaction duct, these electrons reaching the anode at a very positive potential after a long and intricate path of travel. Independently of these causes, the applicant's research has established a new cause. Electrons leaving the cathode at the potential zero and which are supposed never to get near the cathodic plate below a well determined value, reach this plate and produce therein a considerable current. This current can still be measured, even if the plate is brought to a certain negative potential with respect to the cathode, for example to $\frac{1}{10}$ of the voltage between the cathode and anode.

The electrons which reach the cathodic plate must have gained energy while those which reach the anode must have lost energy.

Contrary to the dense electron beam in a fieldless space which increases in width owing to the repulsion of the space charges, the electron beams in a space with crossed electric and magnetic fields cannot increase in width unless there is an exchange of energy between the beam electrons. It has been ascertained that between the upper and the lower parts of the beam, an exchange of energy occurs, which is the higher as the beam space charge is higher. The result is an increase in the width of the beam towards the anode and towards the cathodic plate. The average space occupied by this beam of increased width can be determined by the measure of its form which depends upon the space charge density, the beam thickness at the start, the operating voltage and the magnetic field applied. In spite of the fact that some electrons of the beam pass from one equipotential to another, this passage does not cause a velocity change in the lengthwise direction of the beam since the po-

2

tential energy necessary for this exchange is subtracted from or added to other electrons needing a reciprocal exchange of potential energy.

The present invention has for its object to decrease the current losses due to widening of the beam, and thus to improve the gain of the travelling wave tubes with transverse magnetic field, by modifying the shape of the beam.

It is a well known fact that the gain factor, i. e. the unit gain per centimeter of distance for a travelling wave tube with transverse magnetic field and including a delay line, decreases when the electronic efficiency increases. Indeed, when the electronic efficiency increases, the beam moves away from the delay line, and the coupling is decreased between the beam and the electromagnetic wave. Furthermore, the gain decreases when the beam current decreases since the number of electrons taking part in the interaction with the wave decreases.

Owing to the increased width of the beam, the gain by cm decreases progressively from the cathode to the tube collector. In order to avoid a gain decrease already at the beginning of the interaction duct, the electronic efficiency should not increase. In other words, the lower portion of the beam should be prevented from moving down towards the cathodic plate owing to the exchange of energy, and the anode should be removed further away from the upper portion of the beam.

The invention will now be described in greater detail with reference to the accompanying drawings illustrating some embodiments of the invention by way of example, and in which:

Figure 1 is a longitudinal section of a portion of a known travelling wave tube with transverse magnetic field;

Figure 2 is a view similar to Figure 1 of the corresponding portion of a tube according to the invention; and

Figures 3 and 4 are views similar to Figure 2 of complete tubes in two embodiments incorporating the invention.

Figure 1 shows a diagrammatic section through a portion of a travelling wave tube with transverse magnetic field as it was known before the application. The electron beam 1 in the form of ribbon (without any high frequency field) propagates from the left side to the right side between the delay line 2 (anode) and the cathodic plate 3. A constant electric field E supplied by the source 7 exists between the anode and the cathodic plate, and a constant magnetic field whose lines of force are exemplified at B is established so as to be perpendicular at the same time to the electric field and to the beam direction. The increased width of the beam due to the exchange of energy, produces a fan-shape beam which meets the surfaces of the cathodic plate and of the anode producing thereby a loss current.

Figure 2 shows a similar portion of a tube provided with a correcting device according to the invention. The plate 3 is no more at an equipotential level, but is more negative at the right side than at the left side, and it has such a potential gradient that the lower boundary of the beam remains plane. The potential gradient is produced by supplying current from the source 4 and passing it through the plate 3 which is made of resistance material. The delay line 2 (anode) will be at a fixed potential and will be curved upwards in such a way that the increase in potential difference between 2 and 3 in proportion to the displacement from the left side to the right side, will be compensated by the increase of the distance between these electrodes, and that the electric field E, given by the ratio of the potential difference to the distance, will be everywhere equal to its initial value. In this manner, all electrons of the beam, as well as those of the lower boundary of the beam as those of the upper boundary, and those of the inside of the beam, will always keep the same velocity, equal to the phase velocity of the delay line incorporated in the anode. Supposing the space charge density to be constant and the electron velocities in the whole beam to be equal, it is easy to ascertain that the average electronic efficiency, that is to say the height of the average trajectory (broken line 8 Figure 2) above the cathodic

3

plate in relation to the cathode-anode distance, is the same approximately all along the tube length as is the case in Figure 1. Moreover, the gain by cm will be higher in the case of Figure 2 than in the case of Figure 1, on the whole length of the beam, since, for equal electronic efficiency, the current is greater on the whole length of the tube.

In dynamic operation, the beam will be in interaction with the electromagnetic wave progressing in the delay line. The static conditions will no longer be quite valid. However, it is known that the dynamic characteristics of the tube depend upon the static characteristics. In this way, the high frequency gain of the tube comprising the above mentioned improvements will always be higher than for the tube which does not comprise these improvements. From a numerical point of view, the total gain increase is about 30%, thus raising, for example, from 15 db to 20 db.

An additional advantage of this tube is that the parasitic auto oscillations are attenuated, if not cancelled. Experiments have shown that certain parasitic oscillations were caused by the cathodic plate current and that they disappear, when this electrode is brought to a potential sufficiently negative for cancelling the passage of current.

Figures 3 and 4 show two examples of embodiment of the device according to the invention. In addition to the elements designated by the same reference numbers in Figures 1 and 2, Figures 3 and 4 show the emissive cathode of the electron gun 5 and the collector 6. In Figure 3 the cathodic plate is constituted by a succession of electrodes whose potential decreases from the left to the right side, the potentials being taken from taps on the resistances 9 of a potentiometer connected to the terminals of the source 4.

This device is particularly advantageous when the operating current and the beam divergence are not previously known. The curved delay line (the anode) 2 is suspended from a rod 10 leading out through an extensible tube with elastic sides 11; the inclination of the delay line 2 may be varied by acting on the rod 10 while the tube is operating. The connections 12 and 13 are used as input and output for the high frequency energy. The whole is contained in a metallic envelope 14 brought to the positive potential of the source 7 and connected to the anode 2 by the extensible tube 11. A measuring instrument 15 inserted in the connection bringing the collector 6 to the envelope potential 14 makes it possible to measure the beam current.

In Figure 4, the cathodic plate 3 is constructed of a resistance material through which the current is made to pass. According to the thickness of this resistance plate, which may vary as shown in the drawing, the potential will be distributed according to the desired law. The curved anode is fixed, but may also be movable if desired.

This device may be applied as well to the guns producing rectilinear trajectory beams, in static operation, as to those producing very undulated trajectories. The system may be applied to any electronic device comprising electric and magnetic fields whose directions are perpendicular and whose intensities may be either constant or variable in time and space. It may, for example, be applied to travelling wave tubes with a transverse magnetic field of plane, cylindrical or coaxial structure, to electronic interaction amplifying tubes, to magnetrons, etc.

What I claim is:

1. An electron discharge tube comprising an emissive

4

cathode, means for establishing a substantially time-constant magnetic field, said cathode being located within said field, the lines of force of the field, in a given direction, being substantially parallel to the surface of the said cathode, two conductors having their surfaces parallel to the lines of force of the magnetic field and defining an electron and wave interaction duct therebetween, the cathode being located adjacent one of the ends of said duct, a terminal connection to the cathode enabling the surface thereof to be brought to a potential differing from at least one of the conductors, terminal connections to the conductors whereby there may be applied therebetween an electrical potential giving rise to a substantially time-constant electrostatic field substantially perpendicular to the said time-constant magnetic field, the higher potential carrying conductor including elements forming an electrical delay line, thereby to produce a radio-frequency field having an electrical component perpendicular to the crossed substantially time-constant electrostatic and magnetic fields, said elements having the characteristics of longitudinal inductances inserted in a Lecher line, and being so dimensioned that the phase propagation velocity of said electrical component along the delay line is less than in space and substantially equal to the velocity of electrons in the duct; the said electron velocity being determined by the ratio of the intensities of the electric and magnetic fields and said lower potential carrying conductor comprising a structure having field-producing points interconnected by portions having substantial resistance and means comprising a potential source connected between the extremities of said lower potential carrying conductor and having its negative pole connected to the extremity of said lower potential carrying conductor more remote from said cathode for carrying successive points of said conductor considered in the direction of said duct to successively decreasing potentials.

2. Electron discharge tube and circuit as claimed in claim 1, wherein the lower potential carrying conductor is composed of a resistive plate, whereby the output current of said potential source produces a voltage drop upon said plate to decrease the potential thereof in the direction of said duct.

3. Electron discharge tube and circuit as claimed in claim 2, wherein the resistive plate is of a variable thickness in the direction of said duct.

4. Electron discharge tube and circuit as claimed in claim 1, wherein the lower potential carrying conductor is divided into a number of separate portions having terminal connections for applying to different portions gradually decreasing potentials in the direction of said duct.

5. Electron discharge tube and circuit as claimed in claim 1, wherein the shapes of said conductors are such that the width of said duct increases in the direction away from said cathode.

References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
2,511,407	Kleen et al.	June 13, 1950
2,607,861	Wagner	Aug. 19, 1952
2,607,904	Lerbs	Aug. 19, 1952
2,643,353	Dewey	June 23, 1953