

May 7, 1957

B. EPSZTEIN ET AL  
TRAVELLING WAVE TUBE WITH CROSSED ELECTRIC AND MAGNETIC  
FIELDS AND TRANSVERSELY DIRECTED BEAM

2,791,717

Filed May 10, 1951

3 Sheets-Sheet 1

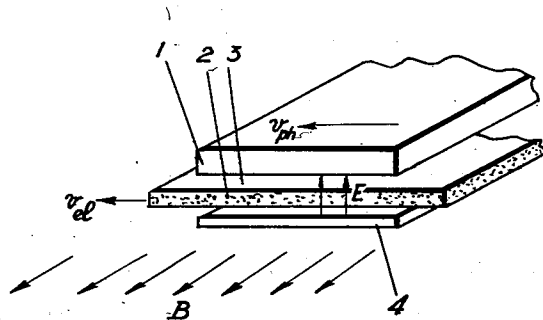


Fig. 2

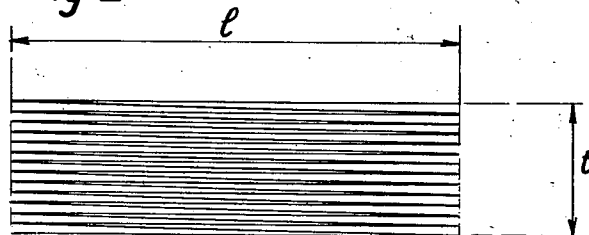
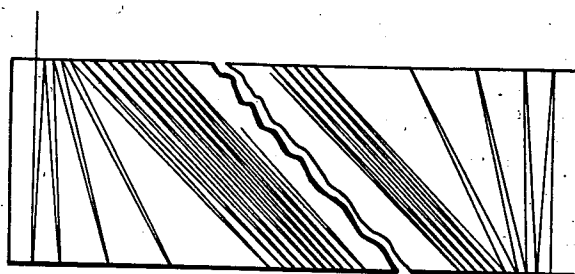


Fig. 3



INVENTORS:

BERNARD EPSZTEIN

HARRY HUBER

By:

Haseltine, Lake & Co.  
AGENTS

May 7, 1957

B. EPSZTEIN ET AL. 2,791,717

TRAVELLING WAVE TUBE WITH CROSSED ELECTRIC AND MAGNETIC  
FIELDS AND TRANSVERSELY DIRECTED BEAM

Filed May 10, 1951

3 Sheets-Sheet 2

Fig. 5

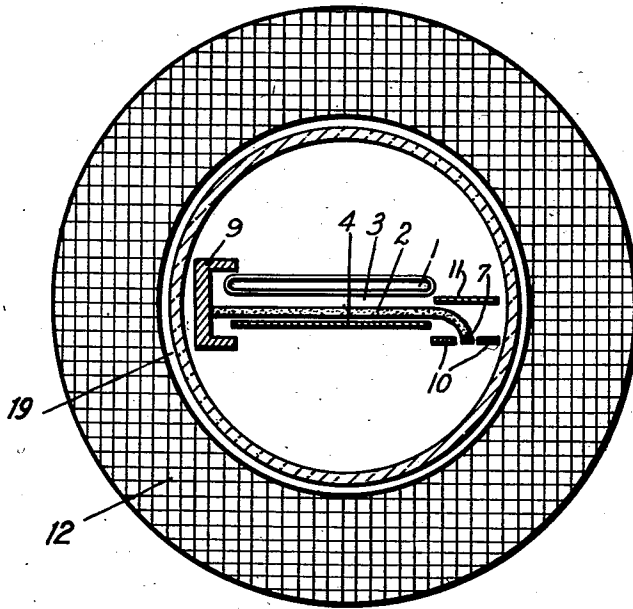


Fig. 6

INVENTORS:

BERNARD EPSZTEIN

HARRY HUBER

BY:

Haseltine, Lake & Co.

AGENTS

May 7, 1957

B. EPSZTEIN ET AL

2,791,717

TRAVELLING WAVE TUBE WITH CROSSED ELECTRIC AND MAGNETIC  
FIELDS AND TRANSVERSELY DIRECTED BEAM

Filed May 10, 1951

3 Sheets-Sheet 3

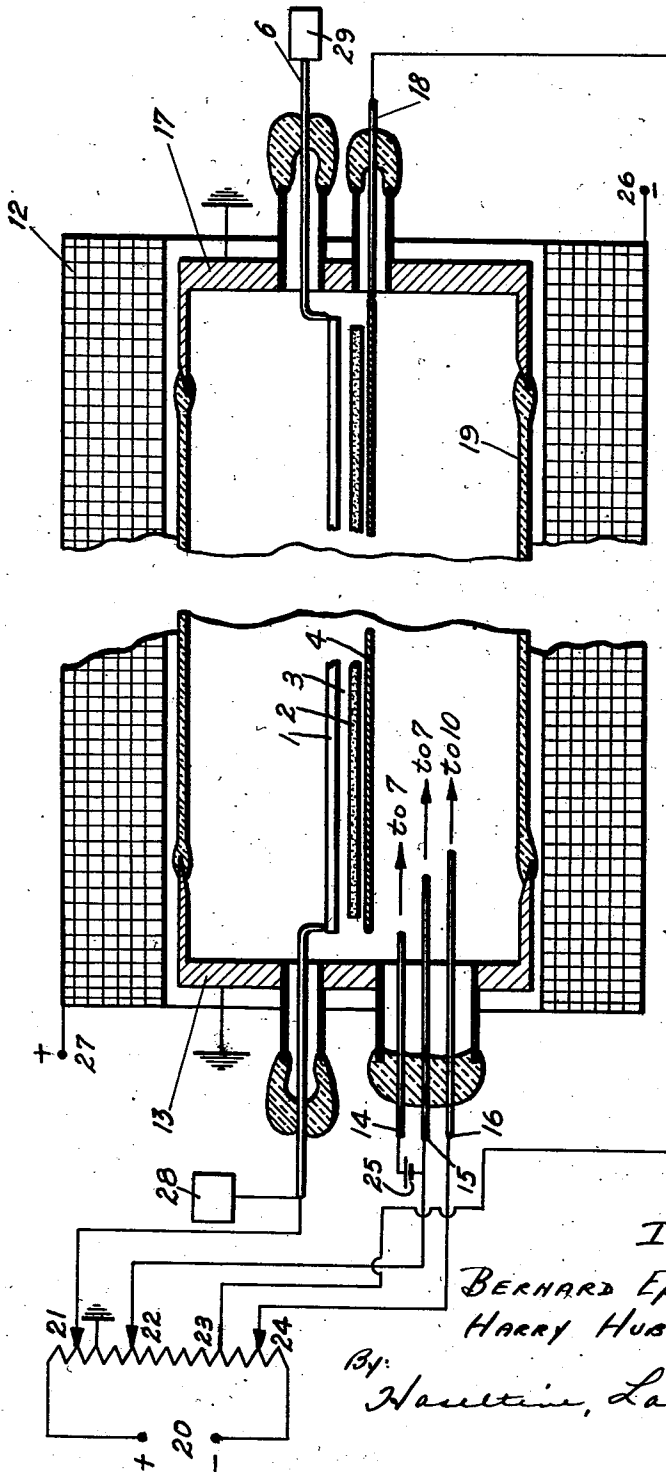


Fig. 7

INVENTORS:

BERNARD EPSZTEIN  
HARRY HUBER

By

Hauettin, Lake & C.  
AGENTS

1

2,791,717

## TRAVELLING WAVE TUBE WITH CROSSED ELECTRIC AND MAGNETIC FIELDS AND TRANSVERSELY DIRECTED BEAM

Bernard Epsztein and Harry Huber, Paris, France, assignors to Compagnie Generale de Telegraphie Sans Fil, a corporation of France

Application March 10, 1951, Serial No. 214,986

Claims priority, application France March 13, 1950

5 Claims. (Cl. 315—3.5)

The present invention relates to a travelling wave tube in which the amplifying effect is obtained by means of an electron beam moving and interacting with a travelling wave inside crossed and time-constant electric and magnetic fields. Tubes of that kind are already known, particularly of a linear form. In these known tubes, the main direction of propagation of the wave and electrons is that of the tube axis (dimension of the length) and the electric and magnetic fields are set towards the transverse dimensions of the tube. According to this invention the tube is so made that the wave and electrons progress mainly in a transverse direction, the vector of the electric field being also transverse, in a direction perpendicular to that of the wave and electrons and the vector of the magnetic field being longitudinal. This difference offers important advantages in connection with the application of the magnetic field, and the gain and efficiency of the tube.

This invention will be better understood when considering the annexed drawings showing respectively:

Figure 1, a schematic perspective section of the arrangement of electrodes, according to the invention;

Figures 2 to 5, examples of embodiment of delay lines that may be applied to the invention;

Figures 6 and 7, an example of embodiment of the tube according to the invention seen in transverse and axial section.

It is known that the interaction between the electron beam and the travelling wave in a tube of the above mentioned type, takes place only if the velocity of the electrons is practically equal to the phase propagation velocity of the wave  $v_{ph}$ . The acceleration velocity  $v_{el}$  of the electrons is determined by the ratio between the intensity of the electric field  $E$  and the induction  $B$  of the magnetic field perpendicular to the field  $E$  and to the direction of the wave propagation:

$$v_{el} = 10^8 \frac{E}{B}$$

if  $E$  is expressed in volts per cm and  $B$  in gauss.

In order to delay the wave, that is, to guide the wave in the direction of propagation of the electrons with a small velocity with respect to the velocity of light, a delay line or delay guide is needed. In known tubes of this type, what has been used for this purpose is any delay line guiding a delayed wave which propagated mainly in the direction of the velocity  $v_{ph}$  along the axis of the tube, while the electron beam propagated in the space included between that delay line and an additional electrode. The electric field  $E$  exists between this additional electrode and the delay line when the latter is at a positive potential with respect to the potential of the additional electrode. The magnetic field  $B$  is generated by a magnet.

As is well known, the tubes of that kind differ from the linear tubes generally known as "travelling wave tubes" (without transverse magnetic field) chiefly by their great efficiency, that is, because their electronic mech-

2

anism enables them to work as power amplifiers. It is known that their efficiency depends largely upon the shape of the electron beam which should be of sheet form, with as little undulation as possible, and propagated very close to and along the delay line. Devices performing the function of electronic gun in such known tubes actually fulfill that condition with sufficient accuracy, but, as experiments have proved, it is still difficult to generate a beam of great intensity, for which reason a tube of convenient power is difficult to construct; the fact that a beam is in the form of a sheet always restricts the current intensity per unit of length to a certain value. Finally, the fact that the length of the gun device in the known tubes is limited by the arrangement of electrodes in the tube, makes it difficult to obtain a substantial increase of the current intensity of the beam.

Another disadvantage of the known tubes refers to the difficulty of obtaining an homogenous magnetic field extending all along the tube. For that purpose, use is generally made of an electro-magnet or a permanent magnet with pole pieces having large surfaces between which the tube is placed. It is evident that such a magnet is very cumbersome and heavy, and that its magnetic field has a great dispersion, two factors which make difficult the construction of tubes sufficient length, a condition which is necessary for higher amplification.

In order to obviate these disadvantages, the present invention provides a new arrangement of a tube of the described type, the principle of which is shown schematically in Figure 1 illustrating a perspective view of the interaction space. In that figure, a delay line 1 of any desired type guides a wave travelling chiefly in the direction of the arrow  $v_{ph}$  transverse to the tube axis; an electronic beam 2 is propagated in space 3 between the delay line 1 and an additional electrode 4;  $E$  is the electric field existing between this electrode 4 and the delay line 1, when the latter, as in the usual tube is at a positive potential with respect to the potential of the additional electrode. The induction magnetic field  $B$  is directed towards the tube axis.

The advantages of this arrangement with respect to the known tubes are the following ones: the electron gun being disposed laterally, its length can be extended all along the delay line; thus a far greater length than before is available, for extending the electron gun so as substantially to increase its total current without losing the above mentioned qualities of concentration. Besides, the magnetic field is very easily obtained, because the tube may be introduced inside a long coil as already known in travelling wave tubes without any transverse magnetic field; therefore, the tube is not practically limited in its length, a condition favorable to the increase of the gun output.

In the construction of such a tube, it is necessary to have a delay line possessing strong components of the phase velocity and of the electric field in the transverse direction of the tube, so that the interaction with the beam is efficient all along the electron trajectory. Indeed, it is not necessary that the wave propagated only in the direction of the beam, and that the high frequency field be only in the same direction, but on the contrary, it is sufficient that only a component be directed in the beam direction. For proper working of the tube, it is even necessary to have a component of the high frequency electric field in the direction of the D. C. electric field, in order that the concentration of the electrons by the high frequency field, and therewith the interaction with the wave, be efficient. This latter condition is fulfilled by the presence of the cathodic electrode 4 shown in the Figure 1.

Such delay lines may be made, for example by means of a wire bent in the form of meanders, or with a flat

helix, by winding the helix wire over a flat mandrel whose width  $l$  is larger than its length  $t$  as shown in Figure 2. Another means of embodiment consists in a series of flat helices, wound over a mandrel, the width of which being about as large as its length. As shown in Figure 3, these elements of helices can be connected in series; it is also possible to connect them in parallel. Other devices using lines of the so-called "vane type" may also be used.

Another example of a delay line fulfilling the above mentioned conditions has been described in the magazine "Electronics," January 1950, pages 100-104, and is shown in Figure 4 which illustrates a flattened helix, wound over a mandrel in such a way that the turns are oblique with respect to the axis. This line is disposed in the tube so that its axis extends parallel to the longitudinal dimension. In that way, there is a strong component of the wave propagation in the transverse direction; the high frequency field of that device has also, in the transverse direction, a component, whose intensity increases exponentially across the width, due to the interaction of the electric field of the turns. In the above mentioned article it has been proposed to use that form of delay line in a travelling wave tube without crossed electric and magnetic fields which is completely different from the subject matter of the present application insofar as the electronic mechanism is concerned.

Figure 5 shows another possibility of constructing the delay line in the form of a plate 1 with "vanes" 20 disposed obliquely, thereby creating properties similar to those of the example of Figure 4.

Figures 6 and 7 show schematically, according to a transverse and an axial section respectively, a non limiting example of a device using a delay line made up according to the above described principles. Figure 6 is a transverse section of the tube where 1 is the delay line, 2 the electron beam, 3 the interaction space, 4 the cathodic electrode, and 9 the collector electrode, the whole being housed in a cylindrical envelope 19. The electron gun is composed of the cathode 7 in the form of a flat tape inserted in the plane electrode 10, and of the auxiliary anode 11, the unit 10-11 being spaced from the system 1-4. The flat beam 2 is generated by means of the electrical field action, of the gun and of the longitudinal magnetic field generated by the long coil 12.

Figure 7 shows the input antenna 5 passing through the plate 13 which carries the auxiliary anode 11 and is traversed by the leads 14, 15, 16 for the connections going to the cathode and the auxiliary cathodic electrode 10. On the other side, the output antenna 6 passes through the plate 17 connected to collector 9 and traversed by lead 18 the connection going to the cathodic electrode 4. The two plates 13 and 17 are joined by the tubular glass enclosure 19.

The plates 13 and 17 are grounded. A battery 20 makes it possible, by means of adjustable taps 21, 22, 23 and 24, to collect the suitable potentials respectively necessary for the delay line 1, the cathode 7, the cathodic electrode 4 and the auxiliary cathodic electrode 10. A battery 25 connected between the leads 14 and 15 provides the heating current for the filament of the cathode 7. Another battery, not shown and connected between the extremities 26 and 27 of the coil 12 supplies the current necessary for the latter. At 28 and 29 respectively are shown the lead-in connections for feeding the high frequency energy to the input 5 of the delay line and the connections for extracting said high frequency energy at the output 6 of the delay line.

What we claim is:

1. An electronic travelling wave tube arrangement including an evacuated envelope having a transverse dimension smaller than the longitudinal dimension thereof; outside said envelope: means for establishing a substantially time constant magnetic field of induction  $B$

with lines of force parallel to said longitudinal dimension; inside said envelope: a cathode, in the form of a flat tape, having an emissive surface substantially parallel to said longitudinal dimension; two spaced substantially parallel conductive structures of substantially rectangular form, having two long sides parallel to said cathode tape and two short sides perpendicular to said tape, said structures defining therebetween an electron and wave interaction space; connections to said structures for producing therebetween a substantially time constant electric field of intensity  $E$ ; means positioned in a predetermined relation with respect to said cathode and parallel structures for concentrating electrons emitted by said cathode in a linear tape-shaped beam propagating in said interaction space in the direction of said transverse dimension with a predetermined velocity equal to the ratio  $E/B$ ; at least one of said two structures being an electric delay line having an input end and an output end, the said delay line having a path for propagation of an ultra high frequency travelling wave between said input and output ends along said interaction space in an average direction perpendicular to said beam and with a propagation component parallel to said beam, said delay line being so dimensioned that the phase velocity of the said wave component propagated along the said delay line in the direction of propagation of the beam is substantially equal to said velocity  $E/B$ ; connections coupled to the input end of said delay line for exciting an ultra high frequency travelling wave therein; a collector electrode for collecting said electrons disposed at the output end of the interaction space; and connections coupled to the output of said delay line for extracting the amplified wave.

2. A tube according to claim 1, in which the said delay line comprises a set of identical flat spirals located in a same plane and having axes parallel to the longitudinal dimension of the said enclosure, disposed so that the planes of their spires of same rank coincide, the dimension along the axis of the said spirals being substantially equal to their perpendicular dimension, and all of them being connected in series.

3. A tube according to claim 1, in which the said delay line comprises a set of identical flat spirals located in the same plane and having axes parallel to the longitudinal dimension of the said enclosure, disposed so that the planes of their turns of same rank coincide, the dimension along the axis of the said spirals being substantially equal to their perpendicular dimension, and all of them being connected in parallel.

4. A tube according to claim 1, in which the said delay line comprises a flat spiral whose axis extends parallel to the longitudinal dimension of the said enclosure, the planes of the turns of said spiral being directed at an angle to a plane perpendicular to the axis of the said spiral.

5. A tube according to claim 1, in which the said delay line comprises a plate with parallel vanes directed obliquely with respect to the direction of progression of the electrons.

#### References Cited in the file of this patent

##### UNITED STATES PATENTS

|           |                      |               |
|-----------|----------------------|---------------|
| 2,241,976 | Blewett et al. ....  | May 13, 1941  |
| 2,439,401 | Smith .....          | Apr. 13, 1948 |
| 2,511,407 | Kleen et al. ....    | June 13, 1950 |
| 2,541,843 | Tiley .....          | Feb. 13, 1951 |
| 2,559,581 | Bailey .....         | July 10, 1951 |
| 2,566,087 | Lerbs .....          | Aug. 28, 1951 |
| 2,607,904 | Lerbs .....          | Aug. 19, 1952 |
| 2,687,777 | Warnecke et al. .... | Aug. 31, 1954 |
| 2,701,322 | Huber .....          | Feb. 1, 1955  |

##### OTHER REFERENCES

Article by Warnecke, Doehler, and Bobot, pp. 279-307, Annales de Radioelectricite for Oct. 1950, vol. 5, No. 22. (Copy in Patent Office Scientific Library.)