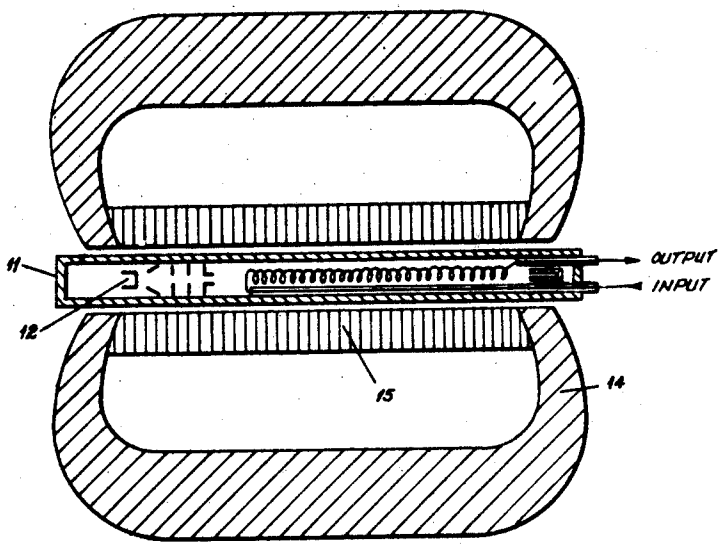
July 21, 1964 P. DELPHIN 3,141,992

FOCUSING SYSTEM FOR O-TYPE TRAVELLING WAVE TUBES

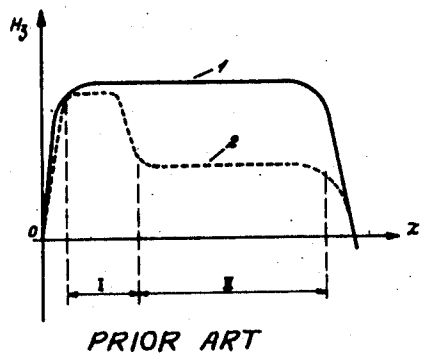
Filed Oct. 9, 1961 2 Sheets-Sheet 1

FIG. 1



PRIOR ART

FIG. 2



PRIOR ART

FIG. 3

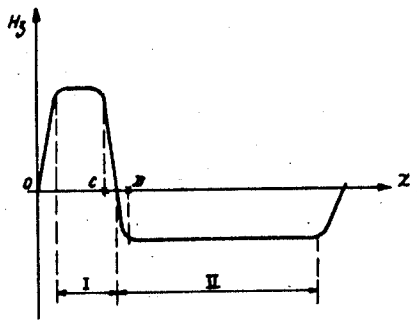


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FIG. 4

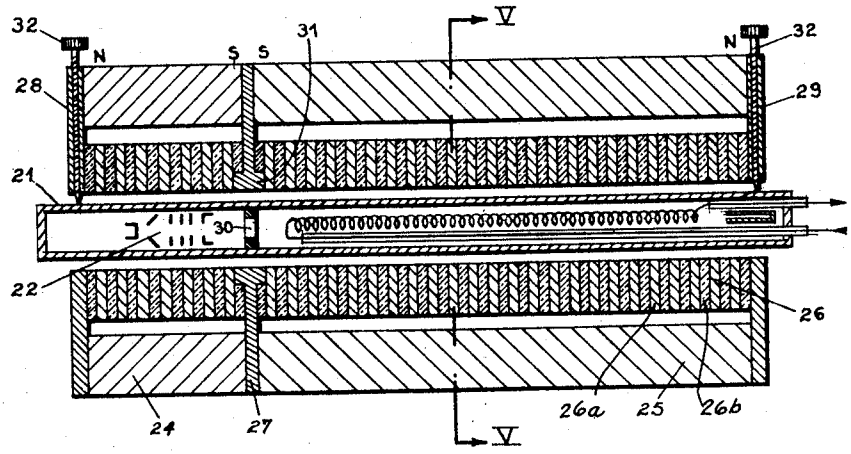
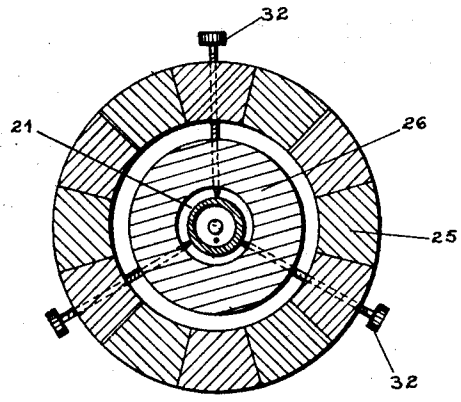


FIG. 5



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FOCUSING SYSTEM FOR O-TYPE TRAVELLING WAVE TUBES

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9 Claims. (Cl. 315—3.5)

The present invention relates to travelling wave tubes, and more particularly to those travelling wave tubes generally referred to as "O-type" tubes in which an electron beam, issued from an electron gun and coupled to a delay line constituted most commonly by a helix, is strongly concentrated by a magnetic focusing field, directed along the axis of the helix. While O-type tubes can be arranged either as amplifiers or as oscillators, and can be operated as forward-wave or backward-wave tubes, it should be noted that no bunching of electrons takes place in this type of tube.

It is known that this focusing field must possess an axial component H_z which is relatively large over a sufficiently small length, corresponding to the electron gun, and a relatively less significant value along the helix, for example, 1000 oersteds over a length of 50 mm. and 500 oersteds over a length of 150 mm.

On the other hand, it is indispensible, in order to obtain a low noise factor, that the magnetic field be perfectly of revolution which all means again that the radial component H_r of the magnetic field all along the axis of the system must be as small as possible.

Currently magnetic fields are realized which fulfill these conditions with solenoids or coils by distributing appropriately the number of ampere-turns thereof. The solenoids, however, present the inconvenience of being cumbersome and space-consuming and of necessitating a special power supply. Additionally, it is normally necessary to cool the solenoids.

It is also possible to produce the magnetic field with the aid of a permanent magnet by realizing the strongest intensity, for example, 1000 oersteds in the aforementioned example, over the entire length of the magnet and by utilizing a magnet of a sufficiently significant diameter to permit introduction of a field straightener intended to reduce the radial component along the axis.

However, it is in practice difficult to realize an efficient field straightener of a diameter smaller than 45 mm. in such a manner that the travelling wave tubes of a length equal to or larger than 200 mm. necessitate magnets of a considerable dimension and weight.

For certain applications there are actually used focusing systems with alternating magnets, however, these prior art systems do not permit the introduction of a field straightener intended, as mentioned hereinabove, to reduce the radial component along the helix. It is therefore difficult to obtain very small noise factors with such a system.

The invention has as its object a new focusing system with permanent magnets which, for given focusing conditions, distinguishes itself by an encumbering and weight which is considerably reduced in comparison with those of the present state of the art.

Accordingly, it is an object of the present invention to provide a focusing system for travelling wave tubes, particularly for O-type travelling wave tubes which eliminates in an effective and simple manner the shortcomings and inconveniences encountered in the prior art constructions.

It is another object of the present invention to provide a focusing system for O-type travelling wave tubes which enables the attainment of relatively low noise factors in such travelling wave tube.

Still another object of the present invention resides in the provision of a focusing system for O-type travelling wave tubes which is of relatively light weight, has relatively small space requirements and dispenses with the necessity of cooling the focusing system.

A further object of the present invention resides in the provision of a focusing system which achieves the aims mentioned hereinabove in an effective manner while at the same time permitting the use of field straighteners for the purposes indicated hereinabove.

These and other objects, features and advantages of the present invention will become more obvious from the following description when taken in connection with the accompanying drawing which shows, for purposes of illustration only, one embodiment in accordance with the present invention, and wherein

FIGURE 1 is a partial cross-sectional view through a travelling wave tube of known prior art construction,

FIGURE 2 is a diagrammatic view representing the magnetic fields realized with the prior art constructions,

FIGURE 3 is a diagram representing a magnetic field obtained in accordance with the present invention,

FIGURE 4 is a partial longitudinal cross-sectional view of a travelling wave tube structure in accordance with the present invention, and

FIGURE 5 is a transverse cross-sectional view taken along line V—V of FIGURE 4.

According to the present invention, the focusing system for the travelling wave tube comprises, in combination, two permanent magnets of cylindrical shape, mounted about the tube with respectively opposite polarities, a common pole piece of soft iron disposed between the adjacent poles of the two magnets and in contact with these poles, two terminal pole pieces of soft iron in contact respectively with the other poles of the magnets, a cylindrical field straightener disposed between the magnets and the tube, and a plate of soft iron having a central aperture, placed on the inside of the tube within the plane of the common pole piece.

The lengths of the magnets are such that one thereof surrounds the electron gun and the other the delay line of the tube, and they are constituted by materials permitting realization of a more intense magnetic field for the first than for the second magnet.

According to a preferred embodiment of the present invention, the common pole piece comprises an enlargement in the vicinity of the tube, intended to improve the rapidity of the inversion of the fields within the interval of separation of the magnets.

Referring now to the drawing wherein like reference numerals are used throughout the various views to designate corresponding parts, and more particularly to FIGURE 1, the focusing system illustrated therein represents a prior art system utilizing a permanent magnet for focusing O-type travelling wave tubes. As may be readily seen from FIGURE 1, illustrating such tube in longitudinal cross-sectional view, the tube **11** with its electron gun **12** and its delay line **13** in the form of a helix, surrounded by a permanent magnet **14** and a field straightener **15** is intended to reduce to a minimum the components of the field which are not parallel to the axis of the tube.

The field produced by the structure of FIGURE 1 is indicated in FIGURE 2 by the curve **1**, shown therein in full lines, in which the abscissae z indicate the distance along the axis of the tube, counted from a point of origin adjacent the cathode and the ordinates H_z are the corresponding axial components of the field.

In the same FIGURE 2, the curve **2** shown in dash line indicates the outline of the field necessary for the operation of the tube, the portion I corresponding to the

electron gun and the portion II to the delay line which is usually a helix.

It may be readily seen from FIGURE 2 that the structure of FIGURE 1 furnishes more magnetic energy than is necessary and, as already indicated hereinabove, the structures of this type attain excessive dimensions and weight as soon as the length of the tubes attains or exceeds 200 mm.

To remedy this shortcoming, the present invention proposes to realize a magnetic field of the form illustrated in FIGURE 3.

It may be readily seen from FIGURE 3 that the fields of the portions I and II are of opposite signs with a stronger intensity in absolute value for the portion I than for the portion II.

It should also be noted, in effect, that the use of two fields of opposite sense is justified by the fact that the focusing energy is proportional to the square of the value of the field and that it, therefore, does not depend on the sign of the utilized field.

FIGURES 4 and 5 illustrate, respectively, in longitudinal and cross-sectional view a non-limitative example of a structure in conformity with the present invention.

The travelling wave tube, shown in longitudinal cross-section in FIGURE 4 is designated therein by reference numeral **21** whereas reference numeral **22** designates therein the electron gun and reference numeral **23** the helix delay line.

The focusing system according to the present invention comprises two permanent magnets **24** and **25** of hollow cylindrical form and a field straightener **26** surrounding the tube **21**. The permanent magnets **24** and **25** have adjacent poles of the same polarity, namely the south poles S in the illustrated figure, on both sides of a common or intermediate pole piece **27** with which they are in contact. The other poles, that is the north poles N of each magnet **24** and **25** in the illustrated embodiment, are in contact with terminal pole pieces **28** and **29**, respectively. The three pole pieces **27**, **28** and **29** are all made of soft iron and are provided with central apertures a little larger than the external diameter of the tube **21**.

The field straightener **26**, of any known construction, is formed of washers alternately of soft iron **26***a* and dielectric material **26***b*, glued or bonded together in any suitable manner.

The pole piece **27** is provided with an enlargement **31** of which the utility will be explained more fully hereinafter.

On the inside of the tube **21**, the system is completed essentially by a plate or disk **30** of soft iron which is disposed in the same plane as the pole piece **27** and is provided with a central aperture for the passage of the beam of electrons issued from the electron gun **22**, the tube being placed into the focusing system in such a manner that the plane of the pieces **27** and **30** is disposed between electron gun **22** and the helix **23**.

The permanent magnets **24** and **25** are constituted by appropriate materials such as, for example, of Ticonal 1500 and Ticonal 800, respectively, to produce a significant magnetic field along the former and a less significant field along the latter, for example, of the order of 1000 and 500 oersteds, respectively.

Centering screws **32** traverse the pole pieces **28** and **29** which permit an adjustment with high precision of the reciprocal position of the tube and of the magnets.

FIGURE 5 illustrates a cross-section taken along V—V of FIGURE 4.

In operation, the electron beam of the tube **21** is, therefore, focussed at first by the magnetic field of magnet **24** and thereupon by that of the magnet **25**. These two fields have opposite directions but the operation of the tube is not subjected to any perturbation from the fact of the inversion of the focusing fields if this inversion is sufficiently steep.

It may, in effect, be demonstrated that this perturbation is avoided if the interval CD along the curve of FIGURE 3 is smaller than

$$\frac{\lambda_c}{4}$$

in which λ_c is the cyclotron wave length, given by the equation

$$c=\frac{2\pi mc}{eB}$$

in which m and e are, respectively, the mass and the charge of the electron, c the speed of light and B the magnetic induction necessary to the focusing of the beam.

This rapidity of the inversion of the fields is obtained in the described embodiment by the combined effect of the pieces **27** and **30** and is, additionally advantageously reinforced and enhanced by the enlargement **31** provided along the pole piece **27**, this enlargement **31** favoring a distribution of the lines of force at an angle in the vicinity of 90° within the region of inversion of the field.

Thanks to the measures described, the weight of a structure with permanent magnets according to the present invention is smaller by about ¼ to that of a structure of a type illustrated in FIGURE 1 and producing the same results.

While I have shown and described one embodiment in accordance with the present invention, it is understood that the same is not limited thereto but is susceptible of many changes and modifications within the spirit and scope thereof, and I, therefore, do not wish to be limited to the details shown and described herein but intend to cover all such changes and modifications as are encompassed by the scope of the appended claims.

I claim:

1. A focusing system for an O-type travelling wave tube provided with a substantially vacuum-tight elongated cylindrical envelope, with electron gun means and with delay line means, said electron gun means and said delay line means being disposed, respectively, in a first relatively shorter portion and in a second relatively longer portion of said envelope, comprising focusing means for producing two magnetic fields of opposite directions extending substantially axially along said two portions of the tube envelope, respectively, with magnetic field intensities having a higher value in said first portion of the tube than in said second portion and including an apertured disc of soft iron located in said tube envelope substantially between said first and second portions, an intermediate pole piece of soft iron surrounding said envelope substantially within the plane of said disc, first and second field straightener means of substantially cylindrical shape surrounding the first and second portions of the tube envelope, respectively, first and second permanent magnet means of substantially cylindrical shape and surrounding said first and second field straighteners, respectively, said magnet means being disposed with mutually opposite polarities and in contact at one of the ends thereof with said intermediate pole piece, and two terminal pole pieces of soft iron surrounding said envelope and in contact with the other ends of said two magnet means, respectively, the respective materials of said two magnet means being so chosen that said first magnet means provides a stronger field than said second magnet means.

2. A focusing system for an O-type travelling wave tube provided with a substantially vacuum-tight elongated cylindrical envelope, with electron gun means and with delay line means, said electron gun means and said delay line means being disposed, respectively, in a first relatively shorter portion and in a second relatively longer portion of said envelope, comprising focusing means for producing two magnetic fields of opposite directions extending substantially axially along said two portions of the tube envelope, respectively, with magnetic field intensities hav-

ing a higher value in said first portion of the tube than in said second portion and including an apertured disc of soft iron located in said tube envelope substantially between said first and second portions, an intermediate pole piece of soft iron surrounding said envelope substantially within the plane of said disc, first and second field straightener means of substantially cylindrical shape and of substantially the same diameter surrounding the first and second portions of the tube envelope, respectively, first and second permanent magnet means of substantially cylindrical shape and surrounding said first and second field straighteners, respectively, said magnet means being disposed with mutually opposite polarities and in contact at one of the ends thereof with said intermediate pole piece, and two terminal pole pieces of soft iron surrounding said envelope and in contact with the other ends of said two magnet means, respectively, the respective materials of said two magnet means being so chosen that said first magnet means provides a stronger field than said second magnet means.

3. A focusing system for an O-type travelling wave tube provided with a substantially vacuum-tight elongated cylindrical envelope, with electron gun means and with delay line means, said electron gun means and said delay line means being disposed, respectively, in a first relatively shorter portion and in a second relatively longer portion of said envelope, comprising focusing means for producing two magnetic fields of opposite directions extending substantially axially along said two portions of the tube envelope, respectively, with magnetic field intensities having a higher value in said first portion of the tube than in said second portion and including an apertured disc of soft iron located in said tube envelope substantially between said first and second portions, an intermediate pole piece of soft iron surrounding said envelope substantially within the plane of said disc, first and second field straightener means of substantially cylindrical shape and of substantially the same diameter surrounding the first and second portions of the tube envelope, respectively, first and second permanent magnet means of substantially cylindrical shape and of substantially the same diameter and surrounding said first and second field straighteners, respectively, said magnet means being disposed with mutually opposite polarities and in contact at one of the ends thereof with said intermediate pole piece, and two terminal pole pieces of soft iron surrounding said envelope and in contact with the other ends of said two magnet means, respectively, the respective materials of said two magnet means being so chosen that said first magnet means provides a stronger field than said second magnet means.

4. A focusing system for an O-type travelling wave tube provided with a substantially vacuum-tight elongated cylindical envelope, with electron gun means and with delay line means, said electron gun means and said delay line means being disposed, respectively, in a first relatively shorter portion and in a second relatively longer portion of said envelope, comprising focusing means for producing two magnetic fields of opposite directions extending substantially axially along said two portions of the tube envelope, respectively, with magnetic field intensities having a higher value in said first portion of the tube than in said second portion and including an apertured disc of soft iron located in said tube envelope substantially between said first and second portions, an intermediate pole piece of soft iron surrounding said envelope substantially within the plane of said disc and provided with an enlarged portion adjacent the tube envelope, first and second field straightener means of substantially cylindrical shape and of substantially the same diameter surrounding the first and second portions of the tube envelope, respectively, first and second permanent magnet means of substantially cylindrical shape and of substantially the same diameter and surrounding said first and second field

straighteners, respectively, said magnet means being disposed with mutually opposite polarities and in contact at one of the ends thereof with said intermediate pole piece, and two terminal pole pieces of soft iron surrounding said envelope and in contact with the other ends of said two magnet means, respectively, the respective materials of said two magnet means being so chosen that said first magnet means provides a stronger field than said second magnet means.

5. An "O-type" travelling wave tube including a vacuum-tight, elongated, cylindrical envelope, an electron gun located in a first, shorter portion of said envelope, a delay line located in a second, longer portion of said envelope, said two portions being spaced apart by a short interval, two cylindrical permanent magnets disposed with opposite polarities around said two portions of the tube envelope, respectively, the respective materials of said two magnets being chosen to produce a magnetic field of a higher intensity in said first portion than in said second portion, an intermediate pole piece of soft iron interposed between said two magnets in contact with one extremity of each of said two magnets, two terminal pole pieces of soft iron in contact with the other extremities of said magnets, respectively, and a cylindrical field straightener disposed between said envelope and said two magnets.

6. An "O-type" travelling wave tube including a vacuum-tight, elongated, cylindrical envelope, an electron gun located in a first, shorter portion of said envelope, a delay line located in a second, longer portion of said envelope, said two portions being spaced apart by a short interval, two cylindrical permanent magnets disposed with opposite polarities around said two portions of the tube envelope, respectively, the respective materials of said two magnets being chosen to produce a magnetic field of higher density in said first portion than in said second portion, an intermediate pole piece of soft iron interposed between said two magnets in contact with one extremity of each of said two magnets, two terminal pole pieces of soft iron in contact with the other extremities of said magnets, respectively, a cylindrical field straightener disposed between said envelope and said two magnets, and an apertured disc of soft iron, disposed within said envelope in said short interval.

7. A focusing system for an O-type traveling wave tube provided with a substantially vacuum-tight elongated envelope, with electron gun means and with delay line means, said electron gun means and said delay line means being disposed, respectively, in a first portion and in a second portion of said envelope, comprising focusing means for producing two magnetic fields of opposite directions extending substantially axially along said two portions of the tube envelope, respectively, with magnetic field intensities having a higher value in one of said portions of the tube than in the other portion and including an apertured disc of soft iron located in said tube envelope substantially between said first and second portions, an intermediate pole piece of soft iron surrounding said envelope substantially within the plane of said disc, first and second field straightener means surrounding the first and second portions of the tube envelope, respectively, first and second permanent magnet means surounding said first and second field straighteners, respectively, said magnet means being disposed with mutually opposite polarities and in contact at one of the ends thereof with said intermediate pole pole piece, and two terminal pole pieces of soft iron surrounding said envelope and in contact with the other ends of said two magnet means, respectively, the respective materials of said two magnet means being so chosen that said first magnet means provides a stronger field than said second magnet means.

8. A focusing system for an O-type traveling wave tube provided with a substantially vacuum-tight elongated envelope, with electron gun means and with delay line means, said electron gun means and said delay line means being disposed, respectively, in a first portion and in a second portion of said envelope, comprising focusing

means for producing two magnetic fields of opposite directions extending substantially axially along said two portions of the tube envelope, respectively, with magnetic field intensities having a higher value in one of said portions of the tube than in the other portion and including an aperture disc of soft iron located in said tube envelope substantially between said first and second portions, an intermediate pole piece of soft iron surrounding said envelope substantially within the plane of said disc and provided with an enlarged portion adjacent the tube envelope, first and second field straightener means surrounding the first and second portions of the tube envelope, respectively, first and second permanent magnet means surrounding said first and second field straighteners, respectively, said magnet means being disposed with mutually opposite polarities and in contact at one of the ends thereof with said intermediate pole piece, and two terminal pole pieces of soft iron surrounding said envelope and in contact with the other ends of said two magnet means, respectively, the respective materials of said two magnet means being so chosen that said first magnet means provides a stronger field than said second magnet means.

9. An "O-type" travelling wave tube including a vacuum-tight, elongated, cylindrical envelope, an electron gun located in a first, shorter portion of said envelope, a delay line located in a second, longer portion of said envelope, said two portions being spaced apart by a short interval, two cylindrical permanent magnets disposed with opposite polarities around said two portions of the tube envelope, respectively, the respective materials of said two magnets being chosen to produce a magnetic field of a higher intensity in said first portion than in said second portion, an intermediate pole piece of soft iron interposed between said two magnets in contact with one extremity of each of said two magnets, two terminal pole pieces of soft iron in contact with the other extremities of said magnets, respectively, a cylindrical field straightener disposed between said envelope and said two magnets, and an apertured disc of soft iron, disposed within said envelope in said short interval, said intermediate pole piece being provided with an enlarged portion near said envelope.

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