Aug. 1, 1967 K. B. NICLAS 3,334,264

BEAM FOCUSING MAGNET SYSTEM

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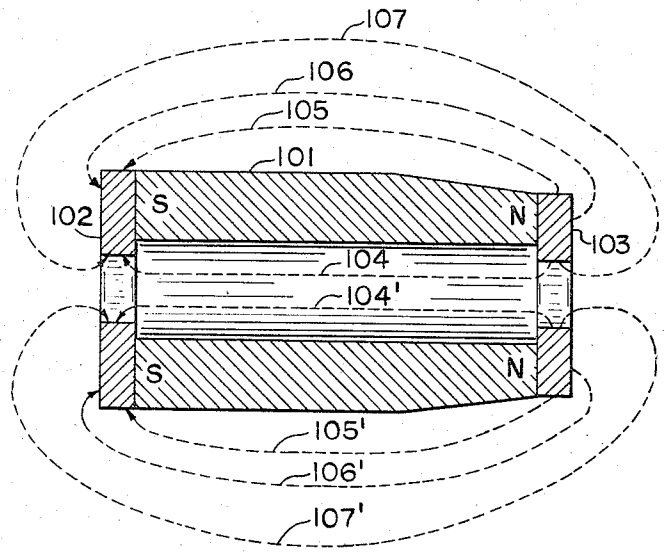


Fig. 1

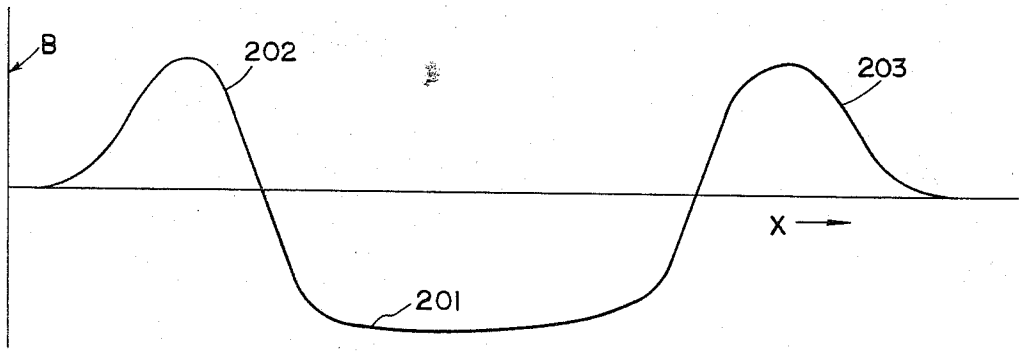


Fig. 2

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BEAM FOCUSING MAGNET SYSTEM

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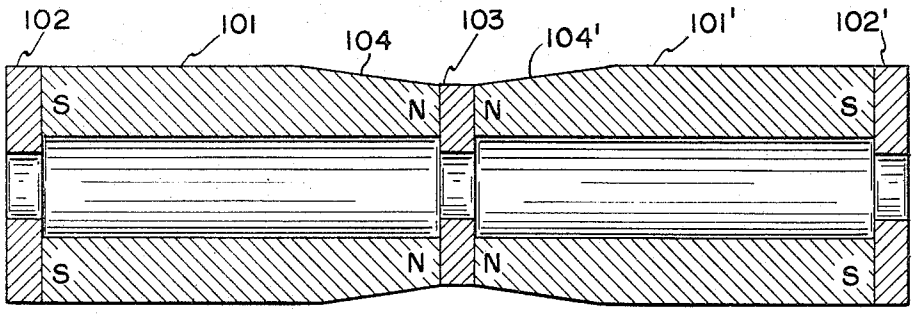


Fig. 3

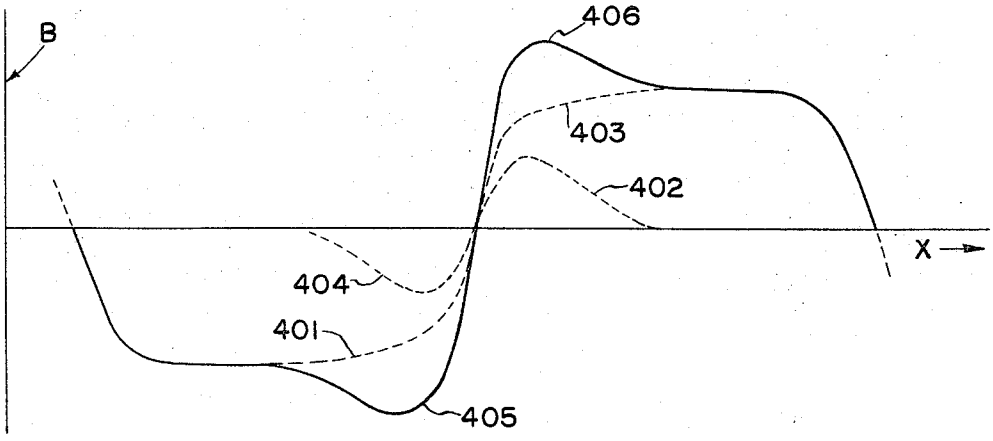


Fig. 4

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BEAM FOCUSING MAGNET SYSTEM

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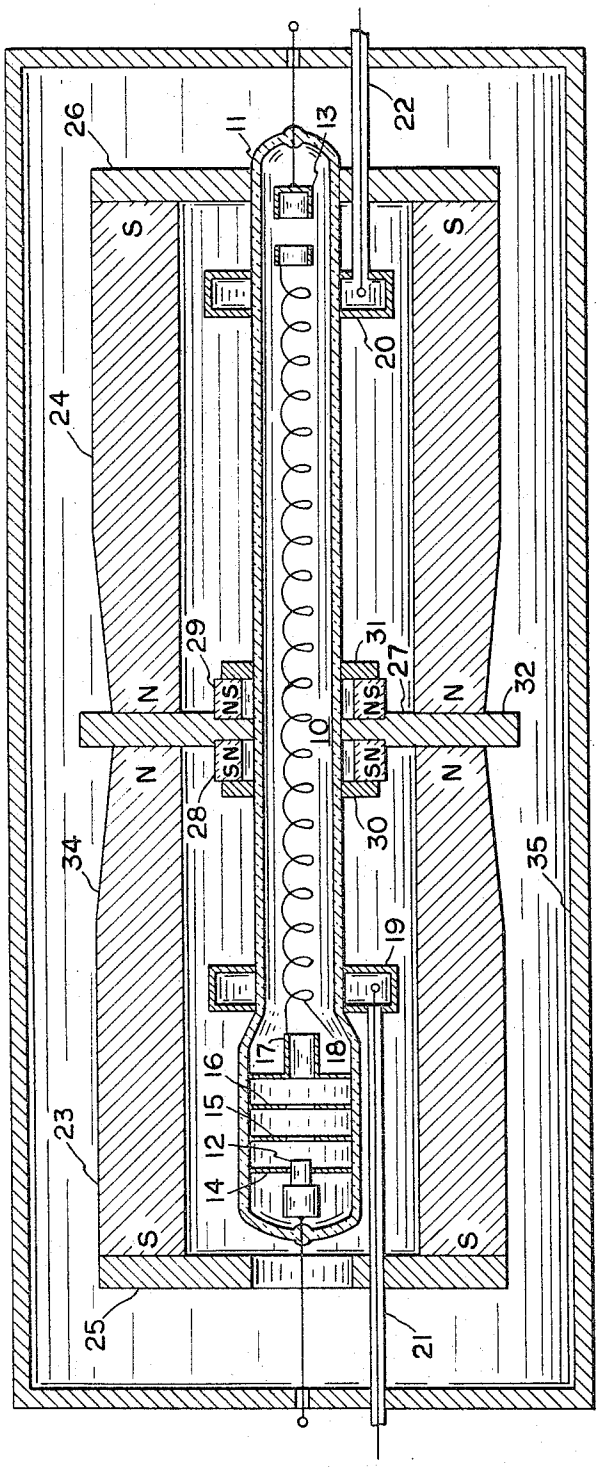


Fig. 5

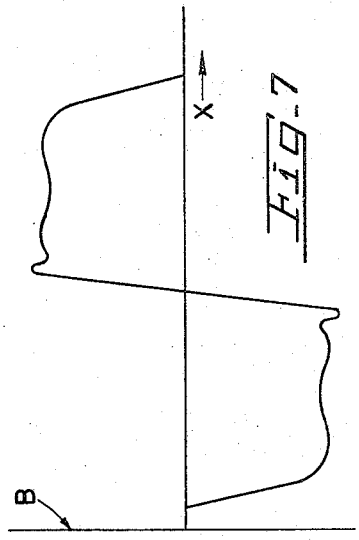


Fig. 7

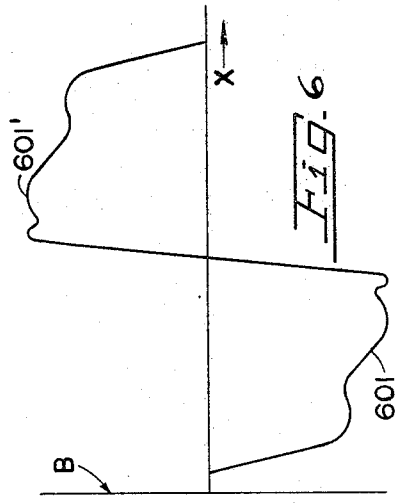


Fig. 6

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BEAM FOCUSING MAGNET SYSTEM

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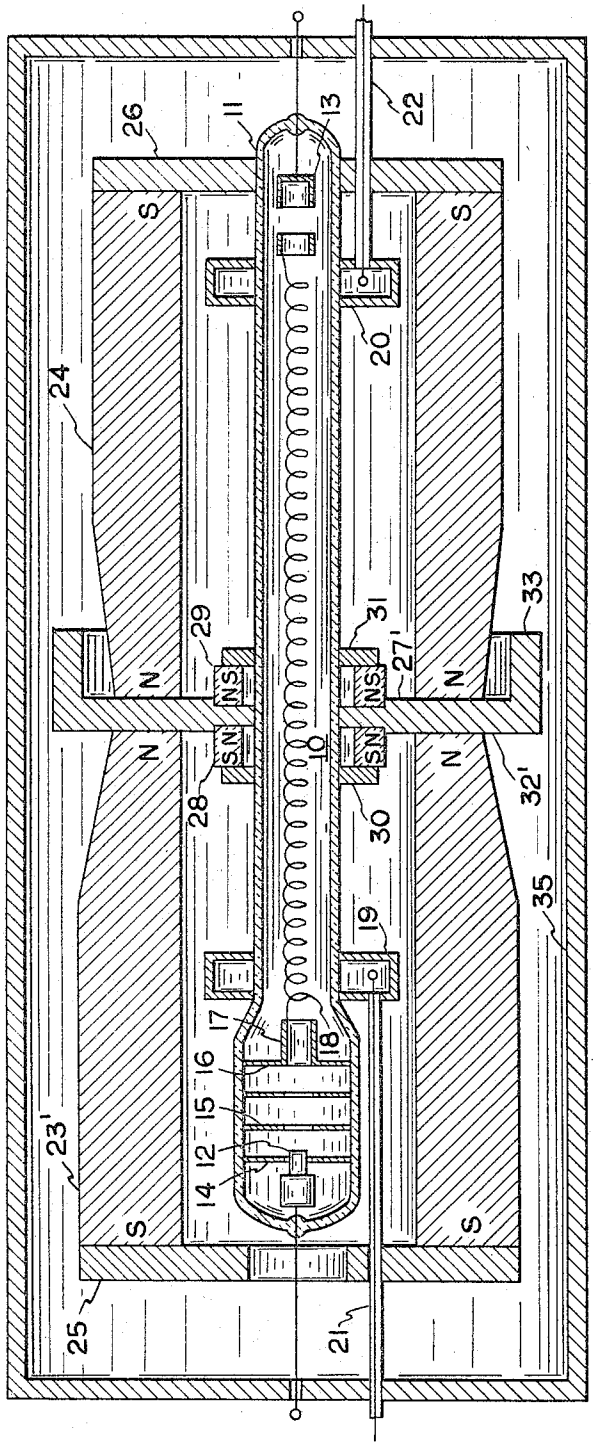


Fig. 8

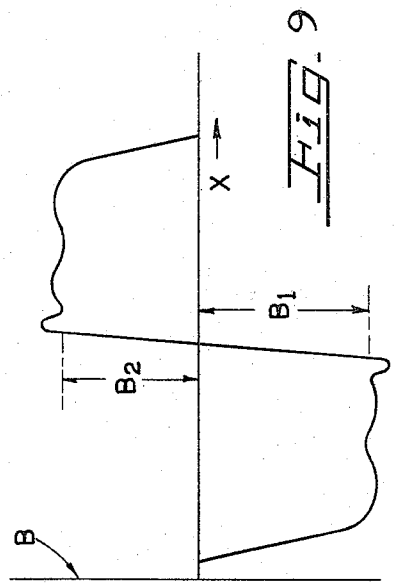


Fig. 9

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BEAM FOCUSING MAGNET SYSTEM

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Filed July 1, 1963, Ser. No. 291,789
10 Claims. (Cl. 315—3.5)

ABSTRACT OF THE DISCLOSURE

A magnet system for a traveling wave tube having a pair of hollow cylindrical main magnets positioned end-to-end and coaxial of said path, adjacent ends of said main magnets being of like magnetic polarity whereby the axial magnetic field along said path reverses direction in the region of the adjacent ends of said main magnets; and a magnetically permeable annular pole piece axially aligned with said path and separating said adjacent ends of said main magnets, said pole piece having an outside diameter greater than the outside diameter of said adjacent ends of said main magnets for deflecting the fringing field of each main magnet from the region of the axial field of the other main magnet.

The invention relates to a magnet system for focusing beams of charged particles. More particularly the invention relates to a magnet system for producing a magnetic field which rapidly reverses direction at least once along a predetermined path and wherein the axial magnetic field along the path on both sides of the reversal zone is substantially uniform both axially and radially. The invention is particularly useful for providing a magnet system of relatively light weight for focusing the electron beam of a low-noise traveling wave tube.

It is now well-known that the weight of a beam focusing magnet system can be substantially reduced by the use of a periodic magnetic field as compared to a uniform field. Such periodic magnetic fields have been discussed, for example, by J. T. Mendel et al. in an article entitled, "Electron Beam Focusing With Periodic Permanent Magnet Fields," Proceedings of I.R.E., volume 42, pp. 800–810, May 1954. An advantage attendant the reduction in weight of the magnet system is the reduction of fringing fields which allows close spacing between tubes or between a tube assembly and other magnetic material without the need of bulky and heavy magnetic shielding.

In typical periodic focusing arrangements a relatively short magnetic period is provided and the axial magnetic field approximates a sinusoid. A short magnetic period minimizes the ripple in the electron beam diameter and allows minimization of the size and weight of the focusing structure. However, short magnetic period structures give rise to nonlaminar electron flow with consequent noise in a traveling wave tube. Thus it has been found that the noise figure of traveling wave tubes focused by short period periodic magnetic fields is in the order of 3 db higher than tubes focused with uniform fields.

It has been found that by using an alternating magnetic field having a longer magnetic period, a significant weight advantage over a uniform field structure can be achieved while providing a noise figure comparable to that obtainable with a uniform field, if the alternating magnetic field is properly shaped. More particularly, it is desirable that the magnetic field change direction in a minimum distance to thereby reduce perturbing affects on the electron beam.

A magnet structure which achieves very rapid direction reversal of the axial magnetic field is shown in a co-

pending U.S. patent application Ser. No. 288,273, filed by Arthur H. Iversen on June 17, 1963, entitled, "Beam Focusing System," and assigned to the same assignee as the present invention. In the magnet system disclosed by Iversen, reversal of the magnetic field in a minimum axial distance is achieved by providing a pair of auxiliary magnets positioned at each reversal junction of the main magnets. These auxiliary magnets serve to reinforce the axial magnetic fields of the main magnets, in the region of their adjacent ends, whereby the length of the reversal zone is reduced with a consequent reduction in the disturbance of the electron beam. Similar auxiliary or aiding magnets are employed in the magnet system of the present invention for the same purpose.

In addition to minimizing the length of the reversal zone, several other factors have been found to play an important part in achieving a low noise figure in a traveling wave tube employing a reversing magnetic field for beam focusing. To reduce perturbing effects on the electron beam, and therefore noise, it is desirable to maintain the axial strength of the magnetic field as uniform as possible between pole pieces.

In reversing field focusing structures a problem arises from the fact that the axial field producing magnets are positioned end-to-end with like poles adjacent in the reversal zone. In such configurations a portion of the fringing field of one magnet is in the same direction as, and therefore adds to, the axial field of the other magnet. This produces undesirable variation, in the form of peaks or humps, in the axial magnetic field intensity. It is desirable to reduce the affect of the fringing fields on the axial fields.

It is therefore an object of the invention to provide an improved magnet system for focusing an electron beam.

It is another object of the invention to prevent the fringing field of one magnet from adding to the axial field of an adjacent magnet.

It is another object of the invention to deflect the fringing magnetic field of one magnet from the region of the axial magnetic field of an adjacent magnet.

For the purpose minimizing noise it is also desirable to provide radial as well as axial uniformity of the focusing magnetic field, since radial variations in beam intensity also perturb the electron beam.

As is well known, the axial field produced, for example, by known ring shaped permanent magnets is not completely uniform radially. This is apparently due to inhomogeneities of the permanent magnet structure which have thus far defied elimination.

As previously mentioned, auxiliary magnets which aid the axial fields of the main magnets are positioned at each reversal junction of the main magnets to reduce the length of the reversal zone. In the preferred form these auxiliary magnets are ring shaped permanent magnets of relatively small inside diameter. Since these auxiliary magnets are therefore relatively close to the electron beam it is desirable to provide means to decrease any radial nonuniformity of their axial fields.

It is therefore another object of the invention to increase the radial uniformity of a magnetic field.

It is also desirable to optimize the performance of a reversing field focused traveling wave tube amplifier, performance being defined for present purposes as reasonable gain with low noise. In traveling wave tube amplifiers the electron beam of which is focused by an alternating magnetic field having a single reversal, it has been found that the performance of the traveling wave tube amplifier is affected not only by the absolute magnitude of the magnetic field strength but also by the ratio of the axial magnetic field strengths on opposite sides of the reversal zone.

It is therefore a further object of the invention to optimize the performance of a reversing field focused traveling wave tube amplifier.

It is another object of the invention to provide high gain with low noise in a traveling wave tube amplifier the electron beam of which is focused by a single reversal magnetic field.

These and other objects of the invention are achieved by providing a magnet structure comprising a pair of main magnets placed end-to-end along the path of the electron beam to be focused with adjacent ends of these main magnets being of like magnetic polarity whereby the axial magnetic field reverses direction in the region of the adjacent ends of the main magnets. The adjacent ends of the main magnets are separated by a reversal pole piece of magnetically permeable material.

To prevent the fringing fields of the main magnets from causing undesirable variation in the intensity of the axial magnetic field, the reversal pole piece is formed with a radially extending portion which intercepts a substantial part of the axial fringing field thus deflecting this fringing field of each main magnet from the region of the axial magnetic field of the other magnet.

As previously mentioned, auxiliary magnets are employed to reduce the length of the reversal zone. These auxiliary magnets are preferable ring shaped and are positioned coaxially with the main magnets and abutting the reversal pole piece. To increase the radial uniformity of the magnetic fields of these aiding magnets, a disk shaped member of magnetically premeable material is positioned adjacent the auxiliary magnet at the end opposite the end abutting the reversal pole piece. These disk shaped members serve to provide uniform radial distribution of the magnetic flux from the auxiliary magnets.

According to a second embodiment of the invention the performance of a traveling wave tube amplifier is optimized by providing a magnetic focusing field of given strength over a first portion of the length of the electron beam whereby low noise is achieved, and a magnetic focusing field of lesser strength is provided over the remaining length of the beam whereby greater gain is achieved than if fields of the same strength were used over both parts of the beam.

Because the strengths of the main magnets in the second embodiment of the invention are different, there is a consequent difference in the fringing fields. To intercept these asymmetrical fringing fields, to thereby reduce the aforementioned undesirable humps in the axial magnetic field, the reversal pole piece is formed with an asymmetrical extension.

The invention is described more specifically with reference to the accompanying drawings in which:

FIGURE 1 is a longitudinal section view of a hollow cylindrical magnet with representative magnetic flux lines;

FIGURE 2 illustrates the direction and magnitude of the axial magnetic field of the magnet of FIG. 1;

FIGURE 3 is a longitudinal section view of a magnet structure comprising a pair of magnets placed end-to-end with like poles separated by a reversal pole piece;

FIGURE 4 illustrates how the axial component of the fringing fields of the magnets of FIG. 3 cause undesirable humps in the composite axial magnetic field of the magnet structure of FIG. 3;

FIGURE 5 is a longitudinal cross section view of a magnet structure for a traveling wave tube amplifier according to a first embodiment of the invention;

FIGURE 6 illustrates undesirable humps in the axial magnet field due to axially directed fringing flux of the main magnets;

FIGURE 7 illustrates the substantial elimination of the undesirable humps in the axial magnetic field by the fringing flux interception structure shown in FIG. 5;

FIGURE 8 is a longitudinal cross section view of a magnet structure for optimizing the performance of a traveling wave tube amplifier according to a second embodiment of the invention; and

FIGURE 9 illustrates the direction and relative magnitudes of the axial magnetic fields of the magnet structure of FIG. 8.

To understand how the fringing field produces undesirable variation of the axial magnetic field and to appreciate how the structure of the present invention substantially eliminates these undesirable variations, it is desirable to consider first the magnetic flux pattern of a single main magnet of the type employed in the magnet system of the present invention.

Such a magnet is illustrated as a hollow cylindrical magnet **101** in FIG. 1. The magnet **101** is fitted with a pair of pole pieces **102** and **103**. Representative lines of magnetic flux are shown, including axially directed flux lines **104** and **104'** of the desired axial magnetic field and fringing flux lines **105–107** and **105'–107'**. (The field represented by flux lines **104** and **104'** will hereinafter be referred to as the main axial field as distinct from axial component of the fringing field.)

The fringing flux represented by lines **105** and **105'** emanates from the circumferential surface of pole piece **103** and returns to the circumferential surface of pole piece **102**. Thus this portion of the fringing field does not disturb the axial field pattern.

However, the fringing flux represented by lines **106**. **106'**, **107** and **107'** emanates in a rightward direction from pole piece **103** and returns in a rightward direction to pole piece **102**. Thus this portion of the fringing field includes an axially directed component which contributes to the axial field pattern of the magnet structure.

FIG. 2 is an illustration of the axial field pattern of the magnet structure of FIG. 1. According to the convention employed in the present description, the part of the magnetic field shown above the X axis is rightwardly directed while the part shown below the X axis is leftwardly directed. Thus the axial field flux density curve of FIG. 2 includes three portions, a pair of rightwardly directed portions **202** and **203**, which represent the axial portions of the fringing field, and a portion **201** which represents the main axial field of the magnet system.

When a pair of magnets such as magnet **101** of FIG. 1 are positioned end-to-end with like poles adjacent, as illustrated in FIG. 3, a part of the axial component of the fringing field of each magnet is superimposed on the main axial field of the other magnet thus producing humps near each side of the direction reversal zone of the composite axial magnetic field. This is illustrated in FIG. 4 which illustrates the composite axial magnetic field as a solid line including a pair of humps **405** and **406**.

In FIG. 4 the main axial field of magnet **101** is illustrated as a dashed line **401** while the oppositely directed axial component of the fringing field of magnet **101** is illustrated as a dashed line **402**. Similarly, the main axial field of a magnet **101'** (FIG. 3) is illustrated as a dashed line **403** while the oppositely directed axial component of its fringing field is illustrated as a dashed line **404**.

Thus it is seen that the hump **405** is the composite axial field curve is caused by the superposition of the fringing field **404** and the main axial field **401**. Similarly, the hump **406** results from the combination of the fringing field **402** and the main axial field **403**. Some relief from this situation can be obtained by tapering the magnets **101** and **101'** over respective portions **104** and **104'** toward the reversal pole piece. The tapering of the main magnets decreases the main axial field along the tapered portions thereof thus compensating to some degree for the superimposed axial fringing flux. However, insufficient compensation for present purposes can be achieved in this manner. Accordingly the present invention contemplates the provision of a structure for intercepting and deflecting the fringing fields whereby the axial component thereof is substantially reduced.

Attention is now directed to FIG. 5 which is a longitudinal cross section view of a traveling wave tube and a magnet structure according to a first embodiment of the invention.

Illustrated in FIG. 5 is a traveling wave tube **10** of the low noise type which is adapted to employ the magnet system of the present invention for focusing its electron beam along the tube axis. The various elements of the tube are enclosed in an evacuated envelope **11** which may be formed of a material such as glass. The various elements of the tube include a cathode **12** which when heated (by means not shown) provides the electrons for the electron beam. Positioned at the opposite end of the tube is a collector electrode **13**. The collector electrode **13** is maintained (by means not shown) at a high potential relative to the cathode **12**. Thus the cathode **12** and the collector electrode **13** define a longittudinal path of electron flow along the axis of the tube.

The tube **10** further includes a plurality of electrodes **14**, **15** and **16** to which appropriate potentials are applied for transforming the noise waves of the electron beam. The electrons emitted by the cathode **12** pass through these electrodes before entering a drift tube **17** from thence the electrons pass through a slow-wave structure, illustrated in FIG. 5 as a helix **18**, to the collector electrode **13**. An input coupler **19** is provided for introduring R.F. energy to the helix **18** and an output coupler **20** is provided for extracting R.F. energy from the helix. The input R.F. field may be applied to the input coupler through a coaxial line **21**. Similary, the R.F. energy may be received from the output coupler **20** by means of a coaxial line **22**. Further features and details of operation of traveling wave tubes of the type illustrated are well known and will not be repeated herein, the present invention being directed to an improved magnet system for focusing the electron beam.

To achieve efficient and low noise operation of a traveling wave tube it is important to minimize variations and disturbances of the magnetic focusing field which can introduce ripple and otherwise perturb the electron beam. According to a first embodiment of the invention, a magnet system for achieving these results comprises a pair of main magnets, illustrated in FIG. 5 as a pair of cylindrical permanent magnets **23** and **24**, a plurality of pole pieces, illustrated in FIG. 5 as a first annular end pole piece **25**, a second annular end pole piece **26** and an annular reversal pole piece **27**, and a pair of auxiliarly magnets associated with the reversal pole piece, illustrated in FIG. 5 as a pair of permanent ring magnets **28** and **29**.

The pole pieces **25**, **26** and **27** are formed of magnetically permeable material such as soft iron, Permalloy, or the like, and there are positioned at the ends and between the main magnets to direct the magnetic flux therefrom to form a longitudinal field along the axis of the traveling wave tube. The thickness of the reversal pole piece **27** should be minimized, consistent with avoiding magnetic saturation thereof, as its thickness influences the length of the reversal zone.

As illustrated in FIG. 5, the main magnets **23** and **24** are placed end-to-end along the path of the electron beam to be focused with adjacent ends of the main magnets being of like magnetic polarity whereby the axial magnetic field reverses direction the region of the reversal pole piece **27** which separates the adjacent ends of the main magnets **23** and **24**. It is noted that main magnets **23** and **24** are illustrated as formed with a tapered portion, such as a portion **34** of magnet **23**, in the direction of the reversal pole piece.

To decrease the length of the reversal zone whereby the deleterious effects of the magnetic field direction reversal is minimized in accordance with the teaching of the previously mentioned patent application S.N. 288,273, the auxiliary magnets **28** and **29** are placed adjacent the reversal pole piece **27** in the region of the reversal zone. The auxiliary magnets **28** and **29** are longitudinally magnetized and are oriented in aiding relationship to the associated main magnets. The magnetic fields of the auxiliary magnets, thus positioned in the reversal region, serve to reinforce the axial magnetic fields of the main magnets in this region whereby a more rapid reversal of direction is obtained and the length of the reversal zone is greatly reduced.

This rapid reversal of direction of the axial magnetic field is shown in FIG. 6 which is an illustration of the composite axial magnetic field of the main and auxiliary magnets including a pair of humps **601** and **601'** caused by the previously discussed axial component of the fringing field.

To reduce these humps whereby the axial magnetic field is rendered much more uniform, the reversal pole piece **27** is formed, according to the present invention, with a radially extending portion **32**. The pole piece **27** with its radially extending portion **32** is formed with an outside diameter which is greater than the outside diameter of the adjacent ends of the main magnets **23** and **24** Thus the extending portion **32** extends above the adjacent surfaces of the main magnets whereby it intercepts and deflects the fringing flux, for example, as represented by the flux lines **107** and **107'** of FIG. 1. The fringing flux thus deflected from the axial path does not provide an undesirable axial component.

The use of this fringing field deflection structure is especially appropriate where the traveling wave tube with its magnet system is mounted, as is the usual case, in a magnetically permeable housing or shield structure such as a shield structure **35** shown in FIG. 5. Such a shield provides a path for and therefore increases the fringing field, and hence the humps, in the axial field in the absence of the reversal pole piece extension **32**. Depending on the dimensions of the main magnets and of the shield structure, an outside diameter of reversal pole piece **27** with its extending portion **32** of between 0.8 to 1.25 times the maximum outside diameter of the main magnets has been found appropriate.

Thus with or without a surrounding shield structure the reversal pole piece extension **32** serves to intercept the detrimental portion of the fringing field and a more uniform axial field results as shown in FIG. 7 which illustrates the axial magnetic field along the axis of the traveling wave tube of the first embodiment of the invention shown in FIG. 5.

As mentioned hereinbefore, the magnetic fields produced by the auxiliary ring magnets **28** and **29** alone are not, in general, radially uniform. Since radial uniformity of the focusing beam is also desirable for low noise performance, a pair of disk shaped members **30** and **31**, formed of magnetically permeable material, are provided, according to the invention, adjacent the magnets **28** and **29** to enhance the uniform radial distribution of the magnetic fields of these magnets. Preferably the disk shaped members **30** and **31** are formed with a smaller outside diameter than the associated ring magnets **28** and **29** for the purpose of decreasing the possibility of interception and distortion of the axial field of the main magnets.

Thus the magnet system according to the embodiment illustrated in FIG. 5 provides a reversing magnetic focusing field which is substantially uniform both radially and axially by which efficient and low noise operation of a traveling wave tube can be achieved.

In the embodiment of the invention shown in FIG. 5, it is assumed that the strengths of the magnets **23** and **24** are substantially equal. For a given traveling wave tube and focusing magnet structure of the type under discussion there is a value of flux density of the axial magnetic field which will provide the lowest noise figure. However, to achieve maximum gain a lower value of flux density is required. It has been found that the noise figure is substantially established in the first part of the tube and that therefore the focusing flux density along

the second or collector end part of the tube can be reduced to provide greater gain without seriously deteriorating the noise figure.

It has thus been found that the performance of a low noise traveling wave tube amplifier can be substantially optimized by providing an axial focusing field of lesser strength along the collector end of the tube than along the electron gun or cathode end of the tube. A second embodiment of the invention which employs this principle is shown in FIG. 8.

In FIG. 8 a main magnet **23'** over the electron gun end of the tube **10** provides an axial magnetic field of greater strength as compared to the axial magnetic field provided by the magnet **24** over the collector end of the tube. This difference in the axial magnetic field strength is illustrated in FIG. 9 wherein B_1 represents the flux density of the leftwardly directed axial magnetic field of main magnetic **23'** and B_2 represents the flux density of the rightwardly directed axial magneic field of main magnet **24**.

The embodiment of the invention shown in FIG. 8 results in increased performance for the following reasons. When the electrons of the beam encounter the radial magnetic flux lines of the reversal zone, the electrons are caused to rotate around the beam axis. Because the energy required for this angular motion is extracted from the energy associated with the axial velocity of the electrons, a radial distribution of the axial velocity occurs. The energy thus extracted for angular motion represents an axial energy loss which reduces the gain of the amplifier in the second part of the tube, that is, the part beyond the reversal zone.

In order to increase the gain in the second part of the tube, the strength of the magnetic field along the axis thereof can be reduced. This reduces the angular velocity of the electrons which results in less loss of axial velocity and hence less loss in gain. It has been found that the product of the absolute values of the flux densities B_1 and B_2 in gauss, should not exceed the value given by 60 times the value of the voltage applied to the helix, or slow wave structure, divided by the square of the radius of the annular cathode, measured in millimeters (where B_1 is the flux density along the axis of the first part of the tube and B_2 is the flux density along the axis of the second part of the tube).

Thus an axial magnetic field of relatively high flux density can be employed along the first part of the tube for low noise while an axial magnetic field of lower flux density can be employed along the second part of the tube for high gain.

It is noted that the reduction of the flux density along the second part or collector end of the tube results in an increase in diameter of the electron beam beyond the reversal zone. Thus the reduction in flux density for gain increasing purposes is limited by focusing requirements such as preventing the electrons from striking the helix. It has been found that optimum performance can be expected with ratios of the absolute values of the flux denisties B_1/B_2 of from 1.1 to 1.35.

In a typical magnet structure according to the embodiment of the invention shown in FIG. 8 the main magnets **23'** and **24** were formed of Alnico VIII, with a length of 3.6 inches and an inside diameter of 1.25 inches. The main magnet **23'** provided an axial flux density of 600 gauss and the main magnet **24** provided an axial flux density of 500 gauss. Noise figures of under 7 db with a small signal gain of over 30 db over the frequency range of 7–10 gc. were obtained.

Because main magnets of different strength are employed in the embodiment of FIG. 8, the fringing fields are likewise unequal, that is, they are asymmetrical with respect to the reversal zone. For this reason an asymmetrical extension of a reversal pole piece **27'** is provided for deflecting the fringing field to thereby prevent the previously discussed undesirable humps in the axial field.

The asymmetrical extension of reversal pole piece **27'** comprises a radial extending portion **32'** from which a flange portion **33** extends laterally in the direction of the weaker main magnet. This asymmetrical deflection structure deflects the asymmetrical fringing fields and substantially eliminates the undesirable axial components of the fringing fields in the region of the reversal zone.

While the principles of the invention have now been made clear in an illustrative embodiment there will be obvious to those skilled in the art many modifications in structure, arrangement, proportions, the elements, materials, and components used in the practice of the invention which are specifically adapted for specific environments and operating requirements, without departing from those principles. The appended claims are therefore intended to cover and embrace any such modifications, within the limits only of the true spirit and scope of the invention.

What is claimed is:

1. In a traveling wave tube having means for establishing a flow of electrons between an electron gun and an electron collector, a magnet system for maintaining said electrons in a beam along the path between said gun and said collector comprising, the combination of: a pair of hollow cylindrical main magnets positioned end-to-end and coaxial of said path, adjacent ends of said main magnets being of like magnetic polarity whereby the axial magnetic field along said path reverses direction in the region of the adjacent ends of said main magnets; and a magnetically permeable annular pole piece axially aligned with said path and separating said adjacent ends of said main magnets, said pole piece having an outside diameter greater than the outside diameter of said adjacent ends of said main magnets for deflecting the fringing field of each main magnet from the region of the axial field of the other main magnet.

2. A magnet system as defined by claim **1** wherein said main magnets are formed with a taper of decreasing outside diameter over a portion of their length toward said adjacent ends thereof.

3. In a traveling wave tube having means for establishing a flow of electrons between an electron gun and an electron collector, a magnet system for maintain said electrons in a beam along the path between said gun and said collector comprising, the combination of: a pair of hollow cylindrical main magnets positioned end-to-end and coaxial of said path, adjacent ends of said main magnets being of like magnetic polarity whereby the axial magnetic field along said path reverses direction in the region of the adjacent ends of said main magnets; a ferromagnetic shield structure spaced apart from and surrounding said main magnets; and a magnetically permeable annular pole piece axially aligned with said path and separating said adjacent ends of said main magnets, said pole piece having an outside diameter greater than the outside diameter of said adjacent ends of said main magnets for deflecting the fringing fields of said main magnets whereby variation of the axial field is reduced.

4. In a traveling wave tube having means for establishing a flow of electrons between an eletron gun and an electron collector, a magnet system for maintaining said electrons in a beam along the path between said gun and said collector comprising, the combination of: first and second hollow cylindrical main magnets positioned end-to-end and coaxial of said path, adjacent ends of said main magnets being of like magnetic polarity whereby the axial magnetic field along said path reverses direction in the region of the adjacent ends of said main magnets, said first main magnet being at the gun end of said tube, said first main magnet producing a greater axial magnetic field than said second main magnet; a ferromagnetic shield structure spaced apart from and surrounding said main magnets; a magnetically permeable pole piece positioned in said region between said adjacent ends of said main magnets; and magnetically permeable means

for decreasing the magnetic reluctance between said pole piece and said shield structure, said means being asymmetrical whereby the reluctance decrease is greater in the direction of the collector end of said tube than toward said gun end of said tube.

5. In a traveling wave tube having means for establishing a flow of electrons between an electron gun and an electron collector, a magnet system for maintaining said electron in a beam along the path between said gun and said collector comprising, the combination of first and second hollow cylindrical main magnets positioned end-to-end and coaxial of said path, adjacent ends of said main magnets being of like magnetic polarity whereby the axial magnetic field along said path reverses direction in the region of the adjacent ends of said main magnets, said first main magnet being at the gun end of said tube, said first main magnet producing a greater axial magnetic field than said second main magnet; and a magnetically permeable pole piece structure positioned in said region between said adjacent ends of said main magnets, said pole piece structure being formed with a radially extending portion having an outside diameter greater than the outside diameter of adjacent ends of said main magnets, said radially extending portion being formed with an axially extending portion in the direction of the collector end of said tube.

6. A magnet system as defined by claim 5 wherein said main magnets are formed with a conical portion of decreasing outside diameter toward said adjacent ends of said main magnets.

7. A magnet system as defined by claim 5 further including auxiliary magnetic field producing devices for producing local axial magnetic fields aiding the axial magnetic fields of said main magnets in said region of the adjacent ends thereof.

8. In a traveling wave tube having an electron gun at one end and an electron collector at the other end for establishing a flow of electrons therebetween, a magnet system for maintaining said electrons in a beam comprising: a plurality of magnetically permeable annular pole pieces axially aligned with said beam including a first end pole piece at the gun end of said tube, a second end pole piece at the collector end of said tube, and at least one reversal pole piece positioned intermediate of said end pole pieces; a plurality of main magnetic field producing devices for producing axial magnetic fields interacting with said beam between said pole pieces, the direction of the magnetic field reversing at each reversal pole piece; auxiliary magnetic field producing devices for producing local axial magnetic fields aiding the magnetic fields of said main magnetic field producing devices in the region of each reversal pole piece; means for increasing the radial uniformity of the axial magnetic fields of said auxiliary magnetic field producing devices including magnetically permeable members positioned to intercept a substantial portion of the axial magnetic field of said auxiliary magnetic field producing devices; a magnetically permeable shield structure spaced apart from and surrounding said magnet system; and means for deflecting the fringing magnetic fields of said main magnetic field producing devices from the region of reversal of the axial magnetic field including means for decreasing the reluctance of the magnetic path between each reversal pole piece and said shield structure.

9. In a traveling wave tube having means for establishing a flow of electrons between an electron gun and an electron collector, a magnet system for producing a substantially uniform magnetic field of given strength along the path between said gun and said collector in a given direction over a first portion of said path and for producing a substantially uniform magnetic field of lesser strength along said path in a direction opposite said given direction over the remaining portion of said path for maintaining said electron in a beam along said path, comprising: a first hollow cylindrical permanent main magnet surrounding said beam over said first portion of said path; a second hollow cylindrical permanent main magnet surrounding said beam over said remaining portion of said path, said first and second main magnets being oppositely poled with respect to said path, said first main magnet producing a magnetic field of greater strength axially of said path than said second main magnet; a magnetically permeable pole piece separating adjacent ends of said main magnets; a first permanent ring magnet positioned adjacent said pole piece, positioned coaxially with said first main magnet and producing an axial magnetic field in aiding relation to the axial magnetic field of said first main magnet; and a second permanent ring magnet positioned adjacent said pole piece, positioned coaxially with said second main magnet and producing an axial magnetic field in aiding relation to the axial magnetic field of said second main magnet.

10. A magnet system for focusing the electron beam of a low noise traveling wave tube along a slow wave structure between an annular cathode and a collector electrode, comprising: a first magnet for producing a magnet field of flux density B_1 axially of said beam in a given direction along a first length of said beam; and a second magnet for producing a magnetic field of flux density B_2 axially of said beam in a direction opposite said given direction along the remaining length of said beam wherein B_1 is greater than B_2 and wherein the product of the absolute values of B_1 and B_2 in gauss is less than or equal to the value given by 60 times the voltage applied to the slow wave structure of the tube divided by the square of the radius of the cathode in millimeters.

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