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FOCUSING MAGNET FOR LONG ELECTRON BEAMS

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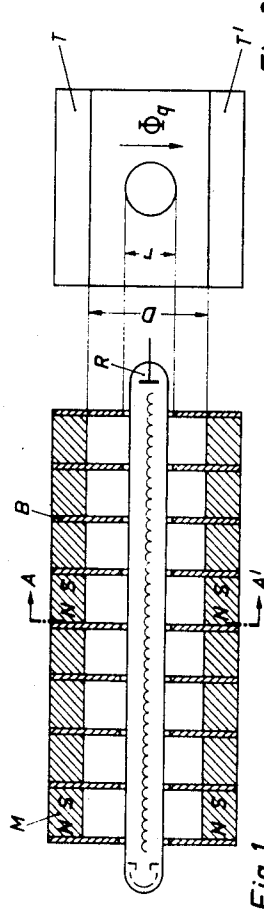


Fig. 1

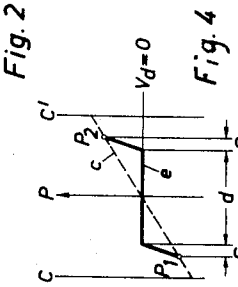


Fig. 2

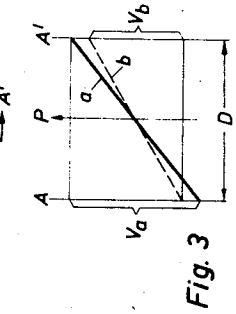


Fig. 3

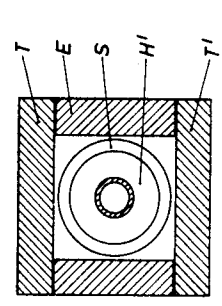


Fig. 4

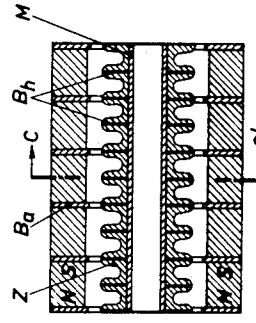


Fig. 5

Fig. 6



Fig. 5a

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FOCUSING MAGNET FOR LONG ELECTRON BEAMS

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This invention relates to focusing magnet structures for long electron beams.

In the production, amplification and modulation of oscillations having a very high frequency electron tubes are used in which there is effected an exchange of energy between an electromagnetic wave and an electron beam of focused electrons of substantial length in proportion to the cross-section thereof. Such types of tube are, for example, the multi-cavity or multi-catcher klystron and the traveling wave tube. The space-charge constants

$$\frac{J}{U3/2}$$

(J=beam current intensity, U=voltage velocity), which are required for such devices, are much higher than, for example, in cathode-ray tubes and necessitate a magnetic beam guidance (focusing) over almost the entire length of the beam. The necessary magnetic force increases with J/U, and the direction of the lines of flux is required to coincide with the direction of the beam if the beam is not to deviate from the desired straight track. This is particularly necessary in the aforementioned types of tubes, since there are usually present very small diaphragm apertures which often must not be hit by the electrons.

The focusing magnetic field may be produced either by electromagnet coils or by permanent magnets. As is well known, permanent magnets are characterized by having less weight and also have the advantage of requiring no magnetising forces and consequently no direct current supply systems.

The field produced by coils, due to the geometry of the winding may be largely determined and may be represented relatively homogeneously, but the field produced by a permanent magnet depends to a large extent on the leakage values of the material employed. Consequently, even with a regular geometrical structure, the resulting magnetic field will exhibit irregularities. Hence there will appear irregular cross-field components whereby the axial coincidence of the longitudinal field with the electron tube inside the arrangement is prevented from being established.

The individual sections which introduce such irregularities cause a deflection of the electron beam out of the desired direction, thereby causing substantial beam current losses and, consequently, a diminution in the amplification and output of the tube. Furthermore, these deflections may result in unduly high heating of the delay line in the tube, which may easily cause the destruction thereof.

For eliminating these disadvantages, arrangements have been proposed in which, by means of soft iron magnetic homogenizing sheet members arranged between the elements of the magnet, there is attempted to achieve a more uniform distribution of the resulting field. In these arrangements, however, the field had to be purposely reduced to such a value lying far below the magnetic field strength which actually could be produced for reasons

that will be apparent in the following description. For this reason permanent magnets could hitherto only be employed with tubes of relatively low gain and output.

In the accompanying drawings:

Figs. 1 to 3 are diagrams used to explain the state of prior art;

Fig. 4 shows a diagram relating to the mode of operation of the invention;

Fig. 5 shows a focusing magnet structure according to the invention, and

Fig. 6 shows a sectional elevation taken on line C—C' of the arrangement as shown in Fig. 5.

One conventional arrangement is shown in Fig. 1 of the accompanying drawing. Around the tube R there is arranged a magnet structure M, composed of individual magnet sections T, T' which produces a longitudinally extending field. The individual magnet sections are magnetized in the axial direction —N, S— and are separated from each other by means of homogenizing sheet members B.

A transverse field will result when, for example, the poles arranged above and below the tube, at A and A' indicating the section line, have different magnetic potentials, and thus have an undesired magnetic difference of potential with respect to one another. This difference of magnetic potential is supposed to be compensated by the adjoining sheet member B serving to short-circuit the common pole surface A, A' of the respective section with a high ferromagnetic permeability.

Fig. 2 is a sectional elevation through the arrangement according to Fig. 1 taken in line A—A'. T and T' denote the upper and the lower partial magnets, while r denotes the central aperture of the sheet members B for receiving the tube R.

Experiments have shown that the desired function of the sheet members B can only be accomplished when the magnet is operated in a "permanent" state, viz. in a state which, after the magnetisation, is substantially weakened. When fully utilizing the field strength of the magnet, however, the internal resistance of the source of magnetic voltage is so low that the flux flowing through the sheet members B easily magnetises them up to the saturation point, thereby limiting the compensation of flux.

The measure of providing continuous sheet members therefore, only brings about a slight improvement of the magnetic field, because the "source of disturbing voltage" cannot be sufficiently "short-circuited."

In Fig. 3 there is shown the magnetic potential P between the poles A and A', which may appear in the case of different properties of the material employed. Curve a in Fig. 3 shows the spacial course when employing no homogenizing sheet, while curve b indicates the potential along the above-mentioned sheet member. The magnetic voltages corresponding to the difference of potential within the total range D with respect to both cases are denoted by V_a and V_b, respectively. It will be clearly seen that the obtained voltage V_b is only slightly smaller than the corresponding voltage V_a.

Now the field strength H, at any point, as is well known, equals the gradient of the potential, hence the only transverse field strength H_t of interest simply equals the derivation of the potential curve which, in both cases and within the total range D, is constant. The weakening of the field obtained with the aid of the conventional homogenizing sheet members, is also evidenced by the reduced slope of the curve b.

There exists, therefore, the problem of further weakening the transverse field, in particular within the mean partial range of D and, if possible, to cause it to disappear entirely.

In accordance with the present invention this is accom-

plished in that the homogenizing sheet members are separated from the magnetic source of disturbance by means of a non-ferromagnetic gap extending in the circumferential direction. By means of this arrangement it is possible to practically eliminate the magnetic difference of potential in the sheet within the gap D. The still-existing transverse difference of magnetic potential is thus effectively removed from the center range, in which it would be likely to affect the electron beam.

The non-ferromagnetic gap extending in the circumferential direction may consist of any suitable material. Since the outside portions of the sheet members, as hitherto, cause only a slight weakening of the magnetic transverse difference of potential, the gap now results in a fundamentally different potential distribution inside its range. Due to its extraordinary high magnetic resistance the gap prevents the passage of a measurable transverse flux Φt, by practically taking up the entire magnetic voltage drop V itself. Since the magnetic resistance Rm of the inner sheet member has remained unchanged, the magnetic difference of potential must have become disappearingly small there because

$$V=\Phi t.Rm \text{ and } \Phi=0$$

Accordingly, in the inner range d also the transverse field strength

$$H_t=\frac{V}{d}$$

is so small that it can be neglected and a sidewise interaction upon the electron beam is precluded.

For appreciating the underlying principle of the invention it should be sufficient to study Fig. 1 and Fig. 2 of the drawings. One only needs to imagine that the homogenizing sheet members B as shown in these figures, besides their central aperture r, comprise a gap of a non-magnetic material extending in the circumferential direction. Hence they should be imagined as being interrupted, e.g. by means of an inserted ring of brass serving, because of its high magnetic resistance, to separate the inner disk with the diameter d (Fig. 4) from the outer sheet member. When comparing Fig. 4 with Fig. 3 the new course of the transverse difference of magnetic potention P (P_1—P_2) between the two partial magnets T and T', originating from the same source of disturbance, will be observed and two very different curves c and e will be noted. The dashed curve c represents the still existing linear course of the potential that is formed outside the gap, hence in the cut-off outer portion of the sheet member B_a. As already described hereinbefore, the latter acts as a flux compensating sheet member between the two poles of the magnet. The inclination of curve c corresponds to a mean value between the curves a and b of Fig. 3, because the sheet member, on account of being cut-off from the inner disk has slightly lost some of its conductivity. The curve e now represents the course of the magnetic potential across the gaps S and within the center range, and exhibits the desirable property of homogenizing the field to an almost ideal extent. It will be obvious that the central aperture r must be just as field-free as the field-free inner plate having the diameter d which serves to short-circuit the high resistance of the aperture. This will be understood when it is appreciated that also the gap at the two points of contact (p_1 and p_2) with the outer flux compensating sheet member, must necessarily have the potential thereof.

In the gap itself, however, there appears a strong potential drop, whereas the middle section of the curve e will extend practically horizontally. The "ascent" thereof, hence the field strength, is μ times smaller because the very weak transverse flux which flows across the gap, also encountered there a μ times greater conductivity. Therewith the inner portion of the sheet provides a practically field-free space which, at the same time, also extends over the central aperture through which the electron beam proceeds.

Hence the invention consists in the provision of a magnet structure comprising homogenizing sheet members surrounding the electron tube, which are not in magnetic contact with the sources of magnetism, for example, the permanent magnet sections.

The precise shape of the homogenizing sheet members is of secondary importance. By way of example, they may either have a circular, oval, square or irregular configuration. The same, of course, also applied to the non-ferromagnetic airgap, the embodiment of which should be adapted to the electrical and mechanical conditions required to be met. Especially the width of the gap may vary if, by way of this measure, there can be obtained a better physical effect in any particular application. The longitudinal field, which effects the focusing of the beam, however, will be partially weakened within the small range of the thin sheet members, but will not be disturbed in its direction as long as the sheet members extend exactly perpendicular in relation to the field axis.

One particular example of an embodiment of the invention which carefully complies with the aforementioned requirements is shown in Fig. 5. In this case the outer flux compensation sheet members B_a are constituted by separate elements, while the homogenizing sheet members B_h are separated from each other by means of spacers Z which are threaded on a non-ferromagnetic supporting means M. In Fig. 5*a* there is shown in section one such spacer, consisting e.g. of aluminum and exhibiting plane-parallel outer surfaces, the other configuration not being critical. It will be seen furthermore from Fig. 5 that the number of inner homogenizing sheet members B_h used may be independent of the number of magnet sections. Hence the outer magnet structure no longer needs to be constructed of numerous very short magnet sections. With respect to the dimensions of the homogenizing sheet members B_h, it has been found that the width of the ring spacers Z has to be chosen as large as possible, at least just as large as the distance between two adjacent sheet members, if it is required to obtain a particularly good homogenization of the inner field. The free inner space which in the case of Fig. 4 is slightly smaller than with the arrangement of Fig. 1, depends on the dimensions of the electron tube to be employed.

Fig. 6 is a section taken on line C—C' through the structure of Fig. 5. The magnet components E, arranged between the magnets T and T', are likewise bar-shaped magnets which are magnetised in the direction of the tube axis and serve to increase the longitudinal field strength.

As has already been pointed out, the shape of the sheet members B_h may be chosen at will. The same applies to the shape of the non-ferromagnetic gap, the width of which may either remain unchanged or, for example, with respect to horizontal or vertically acting influences along its extension, may be varied at will.

In one embodiment of the invention, even when employing permanent magnets with considerable leakage, there could be traced no measurable transverse field strength. When compared with the conventional arrangements employing continuous homogenizing sheet members, the invention has the added advantage that by the employment of such inner members projecting into the range of the outer field of the magnet structure, the inner field cannot be influenced. The invention offers moreover the possibility of eliminating in the same way also the transverse field of coil magnets, which therefore do not need to be wound so carefully as would otherwise be required.

The aforementioned exemplified embodiments are given for enabling a proper understanding of the invention but they, in no way, are intended to limit the scope of the invention or its range of practical application.

What is claimed is:

1. Magnet structure for focusing an elongated electron beam, comprising a plurality of magnetic field-producing elements located adjacent each other along the axis of the beam, said field producing elements having their opposing surfaces of opposite polarity to produce a longitudinal magnetic field extending along the trajectory axis of said beam, first and second field-homogenizing means of high magnetic permeability and extending transversely to the axis of said beam, each of said first field-homogenizing means being positioned between two adjacent magnetic field producing elements, said second field-homogenizing means being positioned between said field producing elements and the axis of said beam, certain of said second homogenizing means being aligned respectively with certain of said first field-homogenizing means, and said first field-homogenizing means transversely spaced from said second field-homogenizing means to form a non-ferromagnetic gap.

2. Magnet structure according to claim 1 further comprising further field-homogenizing means, each of said further field-homogenizing means located between two adjacent of said second field-homogenizing means, said further homogenizing means being of high magnetic permeability and located between said field-producing elements and said axis to define an additional non-ferromagnetic gap between said further means and said field-producing elements.

3. Magnet structure according to claim 1 in which

said second field-homogenizing means is in the form of an annulus and said first field homogenizing means is also in the form of an annulus surrounding the said second field-homogenizing means but having an inner diameter which is larger than the outer diameter of said second field-homogenizing means to provide said non-ferromagnetic gap.

4. Magnet structure according to claim 3 in which the said second of said field-homogenizing means are threaded on an axially supporting tubular non-magnetic member and spaced along said tubular member by intervening non-magnetic spacers.

5. Magnet structure according to claim 1 in which each of said field-producing elements is a permanent magnet each polarized in the same way along the said axis, and in which said first field of each homogenizing means adjacent the said magnets is sandwiched between the adjacent ends of a pair of such magnets.

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