Feb. 9, 1971 C. M. DE SANTIS ETAL 3,562,683

QUADRUPOLE FOCUSING OF ELECTRON BEAMS

Filed April 7, 1969 2 Sheets-Sheet 1

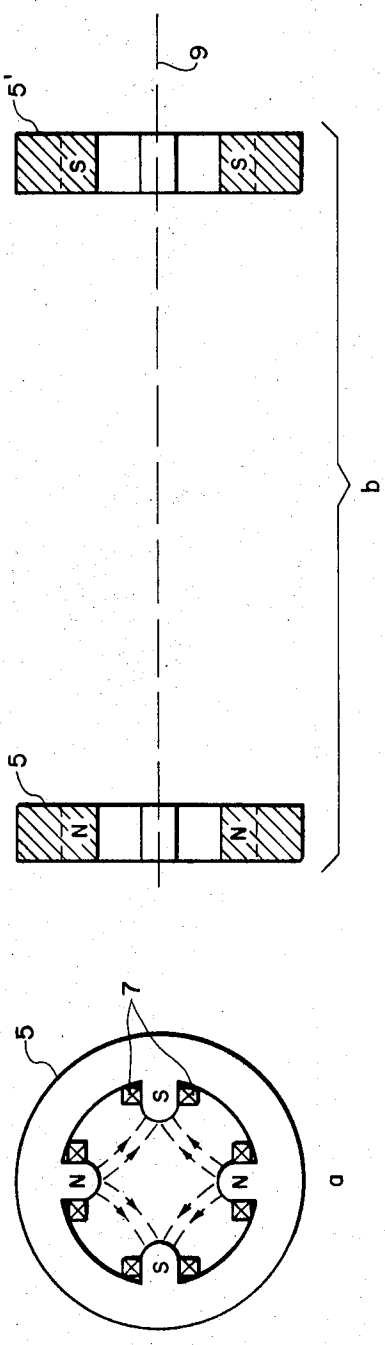


FIG. 1 (PRIOR ART)

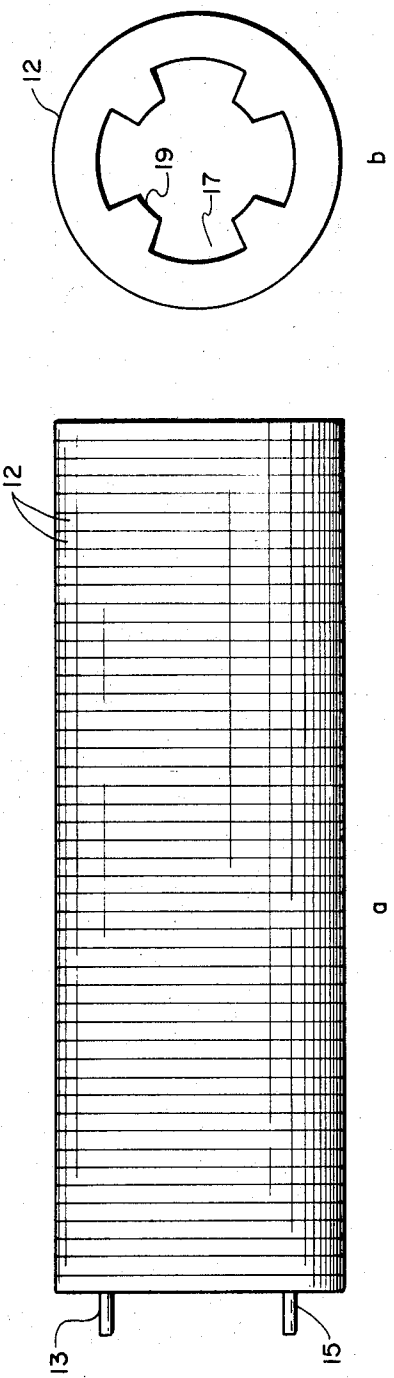


FIG. 3

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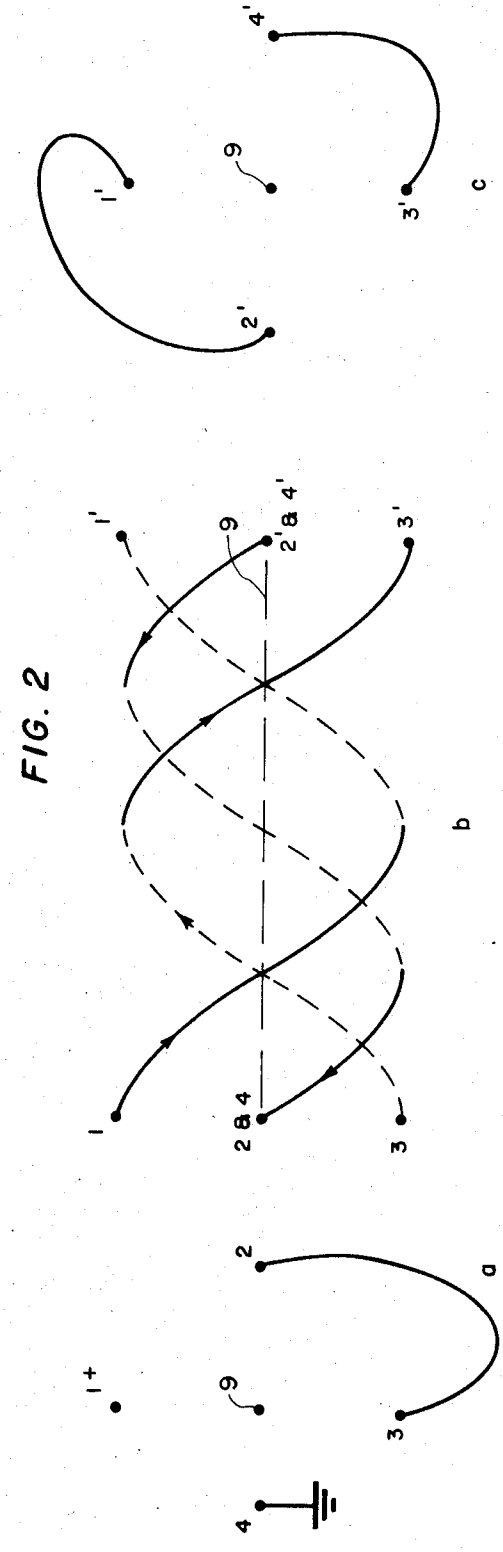


FIG. 2

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QUADRUPOLE FOCUSING OF ELECTRON BEAMS

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U.S. Cl. 335—213 3 Claims

ABSTRACT OF THE DISCLOSURE

A focus coil assembly compirses four intertwined helices surrounding an electron beam to-be-focused. Oppositely directed currents in adjacent helices produce a continuous and distributed quadrupole magnetic focusing field. Field concentration can be achieved by means of a magnetic yoke surrounding the helix assembly.

The invention described herein may be manufactured, used and licensed by or for the Government for governmental purposes without the payment to us of any royalty thereon.

This invention relates to a magnetic focusing means for electron beams and more particularly to a novel and useful quadrupole focusing means comprising a number of current carrying wires disposed around and along an electron beam so that continuous or distributed quadrupole focusing of the beam is achieved. Quadrupole focusing has been used in the past in particle accelerators and other high energy devices by utilizing a pair of lumped focusing magnets or windings located at discrete points along the beam. Since each such lumped quadrupole focusing means focuses the electrons in only a single direction, at least a pair of such means is required, with their focal axes displaced by 90 degrees, thus providing omnidirectional focusing. These prior art lumped focusing coils or magnets have not been extensively used because of the large diameter required of the focusing windings, pole pieces, and yokes. The present invention comprises a single or unitary focusing coil assembly adapted to surround an electron beam to provide a continuous field which field rotates in direction as it progresses along the electron beam, so that a continuous quadrupole field results. Thus the coil is distributed over a large area and the outside dimension thereof is reduced, and also the resulting continuous focusing is more effective than the lumped focusing of the prior art. The distributed field may be provided by means of four helically twisted and intertwined current-carrying wires arranged 90 degrees apart around the electron beam to-be-focused. Direct current is sent through adjacent coils in opposite directions to establish the required quadrupole field.

It is thus an object of the invention to provide a continuous or distributed quadrupole focusing means.

A further object is to provide a quadrupole magnetic electron beam focusing means of small outside dimensions.

Another object is to provide an economical and compact unitary magnetic focusing coil for use with cathode ray tubes.

These and other objects and advantages of the invention will become apparent from the following detailed description and drawings, in which:

FIG. 1 is a pictorial view of a pair of prior art focusing means.

FIGS. 2 and 3 are schematic diagrams of focusing coils constructed according to the present invention.

FIG. 1 shows a pair of lumped prior art quadrupole focusing coils with their yokes. In the end view of FIG. 1*a* it is seen that each such assembly comprises a ring-shaped yoke **5** with four internally-projecting pole pieces spaced at 90 degree intervals thereon. Each pole piece has a winding **7** thereon and the current in each of the four windings is in such a direction that diametrically opposite pole pieces are of the same magnetic polarity, as shown by the letter "N" and "S" thereon. FIG. 1*b* shows a side view of a pair of these focus coils disposed along an electron beam, the direction of which is indicated by the dashed line **9**. As mentioned above, two such lumped focus coils are required with a 90 degree spacing between the magnetic axes thereof. Thus the left hand coil, **5**, of FIG. 1*b* has its two north poles in the vertical plane and the right hand coil, **5'**, has its south poles in the same plane, so that the magnetic field pattern will have the required twist. The field line patterns within each focus coil are shown in FIG. 1*a* by the dashed lines, the flux direction following the north to south pole convention.

FIG. 2 is a schematic diagram showing how four intertwined helices can be connected to provide a continuous, distributed quadrupole focusing coil of unitary structure. FIG. 2*b* is a side view and the two end views of FIGS. 2*a* and 2*c* show how the helix ends are electrically connected to achieve the desired quadrupole field pattern. The opposite ends of each of the one-turn helices are labelled **1–1'**, **2–2'**, **3–3'** and **4–4'**. The solid lines in FIG. 2*b* indicate that this part of the helix is in front of the helix axis **9** and the dashed line portions are to the rear of the axis. Thus the first helix starts at point **1** directly above the helix axis **9** and progresses after **1** turn to the same relative position, **1'**, at the right hand end. The second helix, **2–2'**, begins 90 degrees away from the first, which puts point **2** and **2'** in front of the axis **9** and toward the viewer in FIG. 2*b*. The third helix **3–3'** begins and ends directly below the axis **9**. The fourth helix **4–4'** is not separately visible in FIG. 2*b* since it is directly behind the second helix **2–2'**, and therefore 180 degrees displaced therefrom. The arrowheads on FIG. 2*b* indicates the directions of the direct currents required in each helix to achieve the quadrupole type magnetic field within the helix. It can be seen that the current direction in each helix is opposite to that of both adjacent helices or, to state the same thing in other words, current direction in each helix alternates as one progresses around the coil periphery. FIGS. 2*a* and 2*c* show how a single D.C. power supply can be used to properly energize all of the helices if the illustrated jumpers are used at either end of the helix assembly. One power supply terminal, shown as positive, is connected to point **1**, points **1'** and **2'**, **2** and **3**, and **3'** and **4'** are connected by jumpers, and the negative or ground power supply terminal connected to point **4**. Each helix is shown as comprising one turn for simplicity of illustration, however, in practice other numbers of turns may be utilized.

FIG. 3*a* is a side view of a focus coil assembly with a pair of terminals **13** and **15** corresponding to points **1** and **4** of FIG. 2. In order to provide magnetic and electric shielding as well as to provide an ironclad magnetic circuit with its attendant advantages, the helix assembly is surrounded with a stack of disc-shaped yokes **12**. FIG. 3*b* shows an end view of one of these discs. It is similar in shape to the yokes **5** and **5'** of FIG. 1. The four recesses **17** in the disc can be designed to accommodate the four helical windings, so that each disc can be screwed or threaded onto the completed rigid helical assembly, which would form a screw thread for each disc. The resulting projections **19** would then form pole pieces which would follow the helical shape of the four helices. If the pole pieces **19** of the yokes **12** are made from permanent magnets with adjacent pole pieces of opposite

magnetic polarity, the helices and the power supply can be eliminated, if the discs **12** are stacked in a helical fashion. An alternate construction, not illustrated, would be to wind magnetic wire around the helix assembly, so that the magnetic wire would fill in all the spaces between the adjacent helices. It would be necessary to insulate the magnetic wire from the helices. Insulation would also be required in the embodiment of FIG. 3 between the magnetic discs and the helix assembly.

Thus it can be seen that the present invention achieves quadrupole focusing with a simpler, less bulky and more compact structure than had been available heretofore. The helical structure may advantageously serve a dual purpose as part of a slow wave structure, for instance in a traveling wave tube. The entire focusing structure may also be located within the evacuated envelope of a cathode ray tube.

It should be understood that we do not desire to be limited to the exact details of construction shown and described, since obvious modifications will occur to those persons skilled in this art.

What is claimed is:

1. An electron beam focusing coil assembly comprising, four intertwined current-carrying helices disposed around and along said electron beam, corresponding points of adjacent helices being displaced by 90 degrees, and means to establish direct current in opposite directions in adjacent ones of said helices.

2. The coil assembly of claim **1** wherein a magnetic yoke surrounds said helices, said yoke comprising a stack of magnetic discs adapted to be threaded over said helices, and insulated therefrom.

3. An electron beam focusing coil assembly comprising, four intertwined current-carrying helices disposed around and along said electron beam at 90 degree intervals, means to establish direct current in opposite directions in adjacent ones of said helices, and wherein a magnetic yoke surrounds said coil assembly, said yoke comprising a stack of magnetic discs adapted to be threaded over said helices.

References Cited

UNITED STATES PATENTS

2,155,514	4/1939	Tolson et al.	313—76
2,243,893	6/1941	Blumlein	313—76
3,284,744	11/1966	Dandy et al.	313—84X

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315—5.35; 313—84