Sept. 1, 1959 MICHIAKI ITO 2,902,622

CHARGED PARTICLE BEAM FOCUSING SYSTEM

Filed April 23, 1956

FIG. 1.

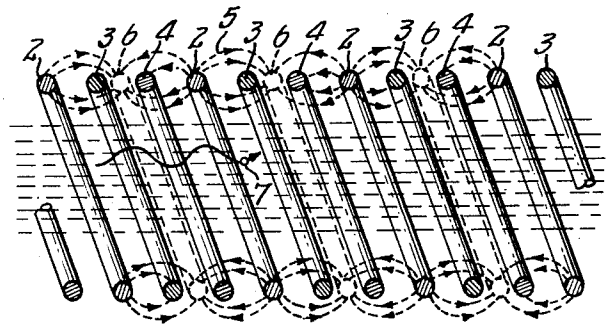


FIG. 2.

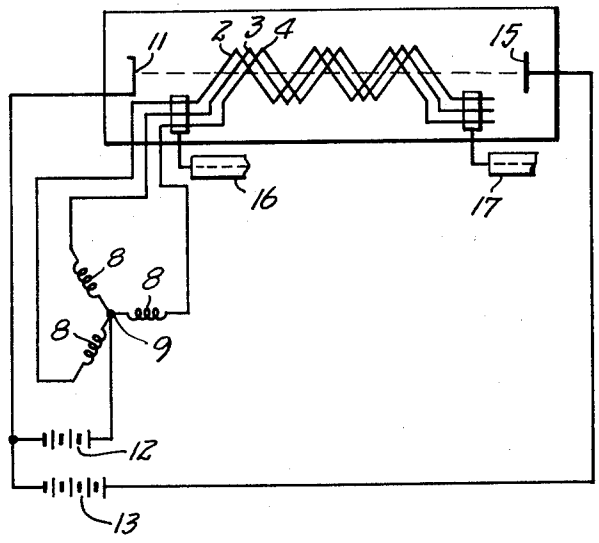
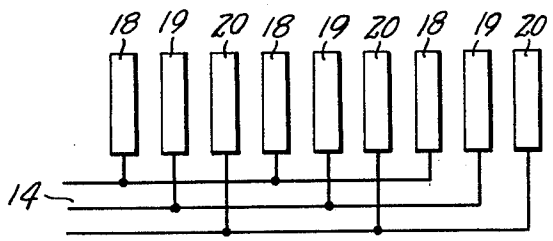


FIG. 3.



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2,902,622

Patented Sept. 1, 1959

2,902,622

CHARGED PARTICLE BEAM FOCUSING SYSTEM

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Application April 23, 1956, Serial No. 579,841

6 Claims. (Cl. 315—3.6)

This invention relates to focusing means for beams of charged particles and is particularly applicable to electron discharge tubes using a relatively long electron beam which must be focused throughout its length, such as is used in traveling wave tubes and the like. The invention may be termed a quasi-static focusing system as distinct from the electrostatic and magnetic focusing systems now in use which uses a direct voltage or current or permanent magnets.

Since the principles of alternate concentration type of focusing for beams was made public in 1948 several methods by which flow of charged particles may be focused, either electrostatically or magnetically, with fields which periodically change in polarity and intensity, have been proposed. For all of these systems however a completely stabilised direct current source has been necessary except in cases where permanent magnets have been used in the magnetically focused beam systems. According to the present invention, an alternating current may be used to achieve the focusing from any multiple phase source such as the normal 50–60 cycle three-phase supply. Although the normal commercial supply is generally preferable because it is convenient to use, the invention is applicable for any multiple-phase low-frequency supply higher or lower than the commercial supply. Also any polyphase power source, such as six or twelve phase systems may be used.

According to a feature of this invention use is made of the relatively long period of the A.C. source supply with respect to the time required for the charged particles forming the beam to traverse the area to achieve the effective steady static field condition during traversal time of these charged particles.

The above-mentioned and other features and objects of this invention and the manner of attaining them will become more apparent and the invention will be best understood by reference to the following description of an embodiment of the invention taken in conjunction with the accompanying drawings, in which;

Fig. 1 is a diagram illustrating an embodiment of the invention used in explaining the operation of the system;

Fig. 2 is a schematic diagram of a traveling wave tube using the focusing arrangement of the type illustrated in Fig. 1, and

Fig. 3 illustrates an alternative type of focusing arrangement incorporating the principles of this invention.

The principle of the invention may be understood from the following description made with reference to Fig. 1. In this figure there is shown three helical coils **2**, **3** and **4**. These coils being of equal diameter and having the turns of the respective coils equally spaced lengthwise one from the other. These coils also surround an electron beam indicated at **1**. To the respective helices **2**, **3** and **4** are supplied three-phase voltages which may be expressed by:

$$E_0 \cos(\theta_1+\omega t)$$
$$E_0 \cos(2/3\pi+\theta_1+\omega t)$$
$$E \cos(4/3\pi+\theta_1+\omega t)$$

respectively. Where E_0 is the maximum voltage θ_1 is the initial phase angle and $\omega=2\pi f$, and f is the frequency of the energy.

Helices **2**, **3** and **4** are insulated from D.C. flow at the lower audio frequencies but may be coupled at opposite ends to sources of ultra high frequency. If the time for passage of a charged particle through the length of the helices is short compared to the period of the alternating potentials applied to the helices, the potentials on the helices may be considered as remaining substantially constant during the travel time of such a charged particle. This fact can be derived by computation but, in view of the order of magnitudes of the relative time periods of the wave and the passage of time of elements or other charged particles, such calculations need not be included for an understanding of the invention.

In electron beam tubes such as traveling wave tubes or backward wave tubes, the electron accelerating voltage generally ranges between several hundreds to several thousands of volts while the length of the helix is at most in the order of a fraction of one meter. Thus the time for passage of a charged particle throughout the length of the helix will be in the order of one hundredth of a micro-second, whereas the period of the alternating current may be in the order of two hundredths of a second. It will thus be clear that the electric field due to an A.C. voltage may be considered as static during the passage time of a charged particle through the length of the helix as the time is too short for any appreciable change to occur. Thus the distribution of the electric field along the length of the helices of Fig. 1 will be substantially as shown in the dotted lines **5**, at any instant of time during which the charged particles are passing through the length of the helix. The electric field will be substantially the same as that which would be generated between the turns of helix **2** and an equivalent helix **6** positioned intermediate the turns of helices **3** and **4**. Accordingly, electrons traversing the length of the helix will be subjected to alternate converging and diverging forces. It can thus be assumed that an electron as indicated by **7** would follow substantially a sine wave curve as indicated resulting in a substantially parallel flow of the electrons thorughout the length of the helices. This effect cannot be achieved by use of a single helix excited by alternating current but is readily obtained with a polyphase supply such as the three phase supply described in connection with Fig. 1.

An example of the application of the principles described in connection with Fig. 1 is illustrated in the schematic arrangement of Fig. 2. In this figure an electron beam from a cathode **11** is projected through the turns of helices **2**, **3** and **4** to a target electrode **15**. During the travel of the beam particles through the helices a high frequency wave applied to the helices **2**, **3** and **4** from an input circuit **16** will be amplified by interaction of the electrons of the beam and the high frequency wave so that the high frequency amplified wave may be taken out at **17**. The three phase supply for helices **2**, **3** and **4** may be furnished from the secondaries **8** of a three phase transformer. As illustrated a Y connection of secondaries **8** is shown and the common point **9** of these secondaries may be connected to a positive terminal of a D.C. source **12**. Thus the helices may be used as the initial accelerating electrodes for the electron beam at the same time they are being used for the focusing of the electron beam and as the delay line for the high frequency energy to be amplified. Another D.C. source **13** is shown connected to the collector electrode **15**.

If any modification of the diameter of the wires used in the helices is desired for the purpose of suppressing

high frequency propagation modes of the waves to be amplified, the variations in the focusing field produced thereby may be compensated by suitable impedance networks connected at the input leads **14** from the three phase supply to the helices.

In the description of Figs. 1 and 2 the invention has been applied to the structure of a traveling wave tube utilizing helices for effecting retardation of the waves to be amplified. However, such a structure is not necessary in accordance with the present invention. Other types of wave slowing devices, such as wave guides, may be used. Furthermore, it is not necessary that the quasi-electrostatic field be produced in a helix. In Fig. 3 is shown an alternative arrangement for producing the effective quasi-static field. According to this arrangement, in place of using three helices, there is shown three sets of rings **18**, **19** and **20** successively positioned substantially in the same manner as the successive turns of the various helices of Fig. 1. These focusing electrodes may then be supplied with polyphase voltages over line **14** from any suitable source such as shown in Fig. 2.

While the invention has been described in connection with the control of electrons, it is clear that the principles of the invention apply to any forms of beams of charged particles, such as ions or other elementary particles.

By the use of this invention it is not necessary to use a magnetic field for focusing a flow of charged particles and thus the weight of the structure can be greatly reduced. Furthermore, complete stability of the electric source is not required as in the case of D.C. electrostatic focusing. So that a much simple source of focusing power can be made.

While the principles of this invention have been described in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation to the scope of the invention as set forth in the objects thereof and and in the accompanying claims.

What is claimed is:

1. A beam focusing system for focusing a beam of charged particles, comprising means for producing a beam of charged particles, a plurality of conductor elements positioned symmetrically and coaxially of the beam, a source of polyphase energy having a period long with respect to the time for passage of particles of said beam through said conductor elements, and means for applying energy of different phases from said source to respective successively positioned of said conductor elements.

2. A beam focusing system according to claim 1, wherein said conductive elements comprise successive turns of helical conductors, said helices having substantially equal pitches and diameters, and being positioned to have equal spacings between adjacent turns.

3. A beam focusing system according to claim 2, wherein said beam is a beam of electrons.

4. A traveling wave tube incorporating a beam focusing system according to claim 3, wherein said electron beam is included in a traveling wave tube, further comprising means for applying a high frequency wave to said helices for interaction with said electron beam.

5. A beam focusing system according to claim 1, wherein said polyphase source is a three phase source, and said plurality of conductor elements comprise the turns of three helices, positioned to have equal spacings between adjacent turns.

6. A traveling wave tube incorporating a beam focusing system according to claim 5, wherein said helices comprise the high frequency energy retarding means of a traveling wave tube, further comprising an electron source and a target electrode positioned at opposite ends of said helices to produce an electron beam coaxially of said helices forming said beam of charged particles, means for applying high frequency energy to one end of said helices for interaction with said electron beam, and means for extracting amplified high frequency energy at the other end of said helices.

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