Sept. 15, 1959 J. S. BELL 2,904,720

ION ACCELERATOR

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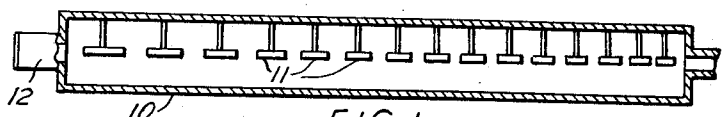


FIG. 1.

FIG. 2.

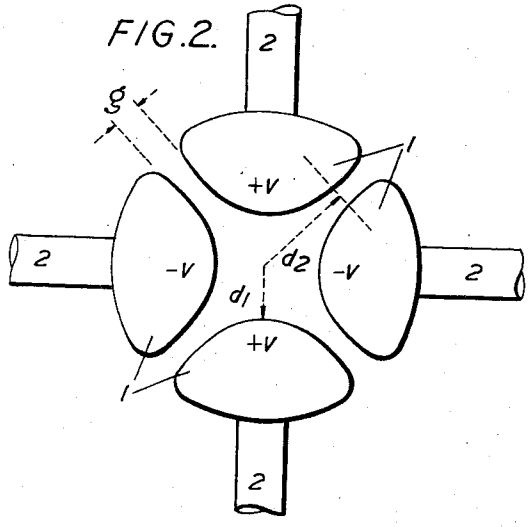
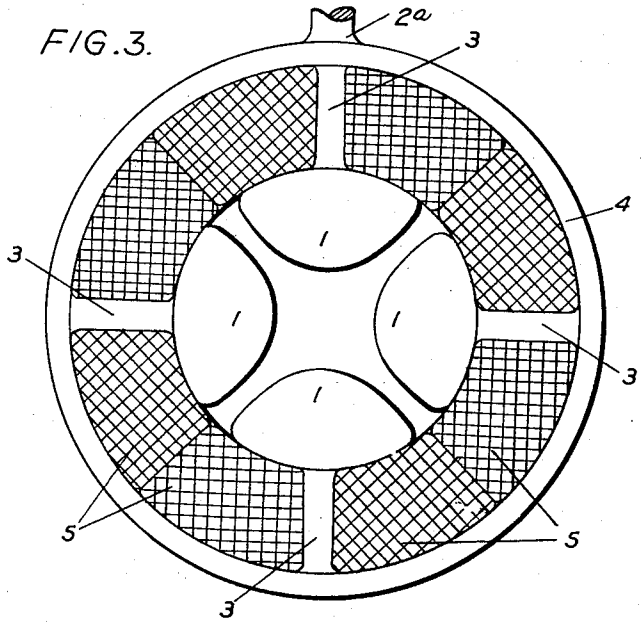


FIG. 3.



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ION ACCELERATOR

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5 Claims. (Cl. 315—5.34)

This invention relates to ion accelerators more particularly for the linear acceleration of protons.

In a linear accelerator ions are injected axially into a wave guiding structure adapted to propagate an electromagnetic wave at a phase velocity related to the velocity of the ions. The ions group themselves in the wave in positions of phase stability in the axial direction and are moved along with the wave. The positions of axial stability, however, are not positions of radial stability and the ions experience fields tending to accelerate them away from the axis.

External focussing means must, in general, therefore be provided to maintain the beam of ions in the neighborhood of the axis of the travelling wave.

Electron beams in linear accelerators are usually focussed magnetically by means of current coils surrounding the wave guiding structure but this method focussing is impracticable when the ions are protons in view of the enormous magnetic field strength which would be required to control the comparatively high mass of the protons unless the wave guiding structure is sectionalised and the magnetic focussing means lumped at positions between the sections to constitute magnetic lenses.

A system of focussing, which may be termed centrifugal focussing, may be used in which the ions are caused to perform spiral orbits about a charged central conductor.

The present invention may be regarded as an inversion of the above described arrangement and comprises means for setting up a field pattern which spirals, or reverses direction periodically about the axis of a purely linear beam, in any section the field being such as to focus the particles along one diameter and to defocus them along a diameter at right angles. The first order equations of radial motion of such a system indicates that the focussing effect is similar to that of a beam spiralling about a conductor supporting a radial field.

The invention is applicable with particular advantage to a linear proton accelerator having drift tubes supported along the axis of a wave-guiding structure and the invention further consists in adapting a drift tube of such an accelerator to provide said field. By changing the orientation of successive tube or groups of tubes the desired spiralling or reversal of the field may be achieved.

Particular embodiments of the invention as applied to a drift tube of a proton linear accelerator will now be described with reference to the accompanying drawing wherein—

Fig. 1 is a diagrammatic longitudinal section of a proton linear accelerator embodying drift tubes,

Fig. 2 is an end elevation of one of the drift tubes shown in Fig. 1 as adapted in accordance with the invention for electrostatic focussing and

Fig. 3 is a view similar to Fig. 2 of one of the drift tubes of Fig. 1 as adapted in accordance with the invention for magnetic focussing. The electrical windings are shown in cross section.

Referring to Fig. 1 the accelerator comprises a resonant cylindrical cavity **10** adapted to be excited in a longitudinal electric mode and provided with a series of drift tubes **11** mounted along the axis of the cavity. A proton source **12** injects protons along the axis. The number and spacing of the drift tubes is arranged according to the velocity of the protons and the frequency of the electric field such that the protons are within and shielded by the tubes during those half periods of the field during which they tend to be retarded thereby, but are exposed to the influence of the field in the spaces between the tubes during the half periods of acceleration. An accelerator in accordance with the invention is provided with drift tubes constructed as shown in Fig. 2 or Fig. 3.

As shown in Fig. 2 the drift tube is divided by four longitudinal gaps into four quadrants **1**, each separately supported by a rod **2** from the inside of the cavity **11**. The gaps g are small so that the R.F. field does not penetrate to the centre of the tube and the shielding action thereof is as effective as a closed tube

Potential differences are applied, via the supporting rods, to adjacent quadrants as indicated so that a beam of particles directed axially through the tube is strongly focussed in one plane and defocussed in a plane at right angles.

The inner surfaces may be circularly concave like those of ordinary drift tubes but the surfaces are preferably shaped as rectangular hyperbolae, as shown, to provide a better field distribution. At the ends of the tubes the shape may be modified or guard rings introduced to avoid asymmetries in the R.F. radial forces.

Calculations indicate that with $d_1=1$ cm., $d_2=2$ cm., $g=.5$ cm., and v. of the order of 6 kv., it should be possible to focus protons of energy about 45 mev. or more in an accelerator with synchronous phase 30 degrees, operating frequency 200 megacycles, and accelerating rate 2.3 mev./metre. The field would be alternated every 3 or 4 drift tubes. With the same accelerating rate and lower velocities the R.F. defocussing forces are larger and correspondingly greater potentials are needed. These can be avoided if the accelerating field is reduced in the initial section of the machine; or alternatively if grid focussing is used in this section.

Protons of 45 mev. travel with almost one third the velocity of light ($\beta=.3$). The electric field of 24 kv./cm. can then be replaced by a magnetic field of 270 gauss by the structure as shown in Fig. 3 in which each quadrant **1** is supported by a web **3** from a yoke **4**, all of magnetic material. The yoke **4** is supported by a rod **2***a* from the inside of the cavity **11**. The field is established over the .5 cm. gap g. The copper needed is 107 amps. per quadrant; with 10 square centimetres of copper winding **5** in each quadrant and a space factor of .75 the power dissipation is 1.2 watts per metre of drift tube. With the same accelerating rate at lower velocity, the magnetic field required is larger; if only the current in the coils is changed then the dissipation per unit length varies inversely as the fourth power of the velocity.

I claim:

1. A linear accelerator of charged particles comprising a wave guiding structure, means setting up a radio frequency field in the wave guiding structure, a plurality of drift tubes each comprising four metallic quadrants positioned about an axis and defining a passageway along the axis of said structure, a source of charge particles positioned at one end of the wave guiding structure to provide charged particles for movement through said passageway, said quadrants being circumferentially spaced to form narrow gaps therebetween of such dimension as to effectively shield said charge particles from the accelerating radio frequency field when passing through the drift tubes, support means for each of said quadrants; and means establishing between adjacent quadrants a

field operative to focus the charged particles passing through said passageway.

2. A drift tube as claimed in claim 1 wherein the support means constitute conductors for applying potentials of opposite polarity to adjacent quadrants; and wherein the field established between adjacent quadrants is an electrostatic field.

3. A drift tube as claimed in claim 1 wherein the quadrants and their supports comprise magnetic material and adjacent quadrants constitute the opposite poles of an electromagnet.

4. A linear accelerator of charged particles comprising a wave guiding structure, a plurality of drift tubes split longitudinally into quadrants supported along the axis of said structure by webs from a yoke, the quadrants, webs and yoke being of magnetic material, and windings on said webs to set up a magnetic field between adjacent quadrants of each tube for focusing the charged particles.

5. A linear accelerator as claimed in claim 4 wherein the focus plane of at least one of said tubes is angularly displaced from the focus plane of a preceding tube.

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