Sept. 1, 1953 W. C. BROWN 2,651,001

ELECTRON-DISCHARGE SYSTEM

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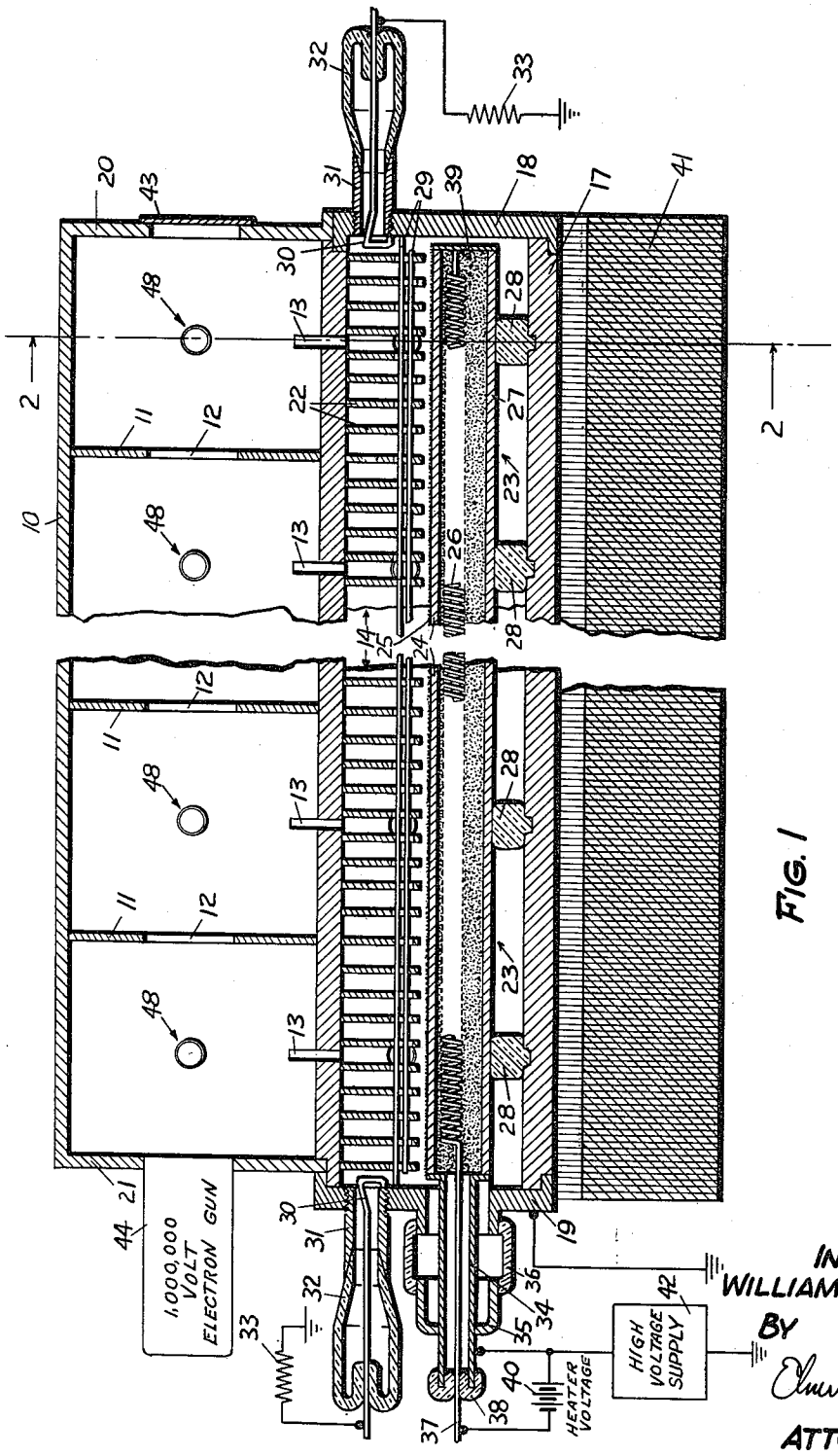


FIG. 1

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FIG. 2

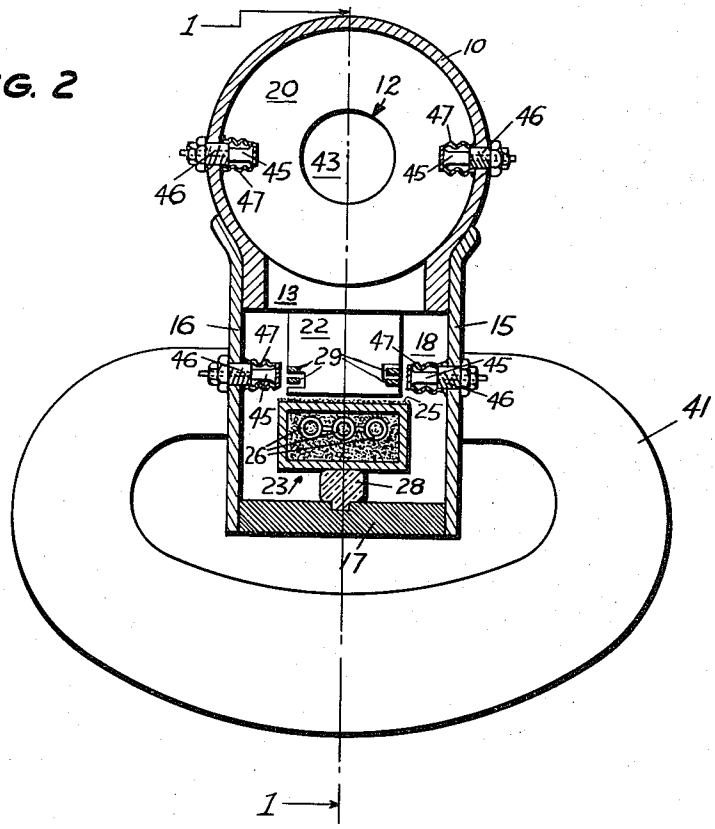
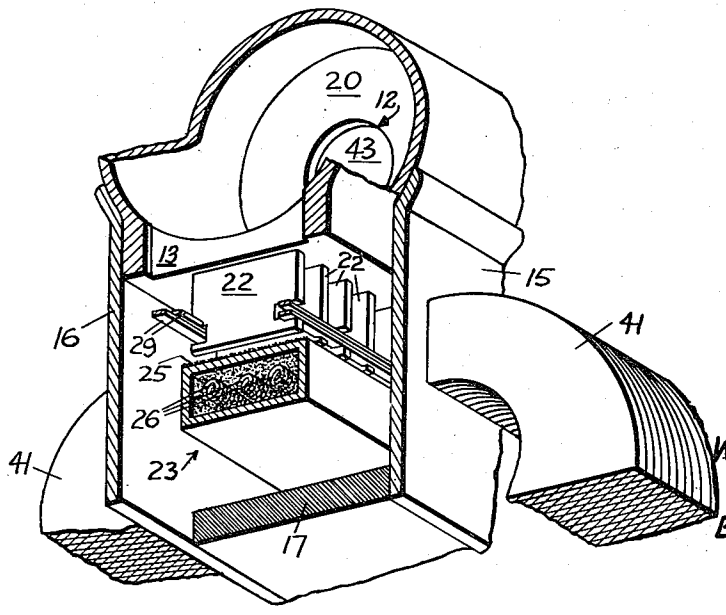


FIG. 3



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ELECTRON-DISCHARGE SYSTEM

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3 Claims. (Cl. 315—6)

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This invention relates to charged particle accelerators, and more particularly to linear accelerators of the synchrotron type.

Linear accelerators of the synchrotron type have not been feasible for producing extremely high particle velocities, for example, on the order of one hundred million electron volts, since the use of a plurality of high-frequency sources to power the accelerator introduced severe problems of synchronizing the phase of the generated energy along the length of the accelerator to produce the desired accelerating fields. Indeed, the problem of synchronizing the energy sources to the accelerator has heretofore required such bulky and expensive apparatus that this type of particle accelerator has been largely passed over in favor of betatron and cyclotron accelerators.

This invention discloses apparatus whereby synchronization of the voltages of the accelerating electrodes may be readily and inexpensively accomplished. Briefly, this is accomplished by using as the accelerating voltage source a linear magnetron extending along the linear accelerating structure with energy coupled from the cavities of the magnetron to the accelerating electrodes of the linear accelerator at discrete points along the lengths thereof.

Specifically, this invention discloses that the coupling between the magnetron and the accelerator may be achieved by slots extending from anode cavities of the magnetron into the spaces between adjacent accelerating electrodes, adjacent accelerating electrodes, together with the cylindrical wall surrounding said electrodes, defining substantially toroidal cavities. It should be clearly undertsood that any desired type or shape of accelerator cavity can be used. Indeed, other forms of accelerating structures such as wire electrodes could be used.

This invention further discloses that, by separating the slots which feed adjacent cavities of the accelerator from the magnetron-anode structure by an even number of cavities in said anode structure between the cavities of said anode structure which feed said slots, or by an odd number of anode vane members, said adjacent accelerator cavities will be fed substantially out of phase with each other, thereby producing the desired accelerating fields.

This invention further discloses that the linear magnetron may be made to operate more stably by terminating the end cavities of the magnetron-anode structure in impedance corresponding to the characteristic impedance of said anode

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structure, and by the use of conductive strapping between alternate anode members of the anode structure.

Other and further objects and advantages of the invention will be apparent as the description thereof progresses, reference being had to the accompanying drawings, wherein:

Fig. 1 illustrates a longitudinal, cross-sectional view of a linear accelerator embodying this invention, taken along line 1—1 of Fig. 2;

Fig. 2 illustrates a transverse, cross-sectional view of the device shown in Fig. 1, taken along line 2—2 of Fig. 1; and

Fig. 3 illustrates a partially broken away perspective view of a portion of the device shown in Figs. 1 and 2 illustrating constructional details thereof.

Referring now to Figs. 1, 2 and 3, there is shown a hollow, cylindrical member 10 which may be made, for example, of any desired conductive metal, such as copper. Spaced along the axis of cylinder 10 and attached to the interior wall thereof is a plurality of metallic disks 11. Disks 11 are spaced along the axis of cylinder 10 transverse thereto at intervals substantially equal to one-half the free space wave length of the frequency applied to the device. For example, if a frequency of 3,000 megacycles is used, spacing between the disk members 11 would be on the order of five centimeters. The disks 11 have holes 12 through their centers coaxial with the axis of cylinder 10, such that charged particles, for example, electrons, entering cylinder 10 at one end thereof may pass through the cylinder 10 along the axis thereof through the holes 12 in the disks 11. It may be seen that adjacent disks 11, together with the space therebetween, form toroidal cavities which may be excited, such that the electrostatic lines therein extend between the disks 11 with the greatest intensities being around the holes 12.

A suitable method of exciting the toroidal cavities comprises slots 13 in the wall of cylinder 10, for example, one slot exciting each toroidal cavity by being positioned substantially half way between the disks 11 defining said cavity and being transverse to the axis of cylinder 10. The slots 13 extend into the cavities of anode structure 14 of a linear magnetron.

The linear magnetron may be of any desired type and structure, the example shown here comprising an evacuated envelope, a portion of which comprises an outer wall portion of the cylinder 10, which, together with side walls 15 and 16 and bottom wall 17, defines the space containing the

anode structure and the cathode assembly of said linear magnetron. The ends of this space are closed by end plates 18 and 19, respectively. The cylinder 10 is also closed by end plates 20 and 21, respectively, such that the entire assembly is vacuumtight.

Extending outwardly from the wall of cylinder 10 into the space defined by side and bottom walls 15, 16 and 17 is a plurality of anode members 22 shown here, by way of example, as rectangular vanes. These vanes are positioned transverse to the axis of cylinder 10, and their edges are spaced from walls 15, 16 and 17. Vanes 22 are rigidly attached, as by silver soldering, to the exterior wall of cylinder 10.

Alternate anode members 22 are connected by conductive straps 29, said straps being connected to the anode vanes at points adjacent the cathode assembly but not between said assembly and said anode members. If desired, the straps which are not connected to the anode members at the end of the anode structure may extend through said members and connect to end plates 18 and 19, respectively.

In addition, in order to insure stability of operation of the magnetron, the end cavities of the anode structure may be terminated in the characteristic impedance of the anode structure in the following manner. Pick-up loops 30 are positioned in the end cavities, one end of the loops 30 being attached to the sleeve 31 inserted through end plates 18 and 19, respectively, and threadedly secured thereto. The other ends of loops 30 extend through sleeves 31 spaced from the walls thereof and through glass seals 32. Outside the glass seals, the loop leads are connected through resistive loads 33 to ground, such as the envelope of the linear magnetron.

On the opposite edges of vanes 22 from the points of attachment thereof to cylinder 10 is positioned a cathode structure 23. Cathode 23 may be of any desired type. For example, as shown here, cathode 23 comprises a planar, metallic member 24 adjacent vanes 22, the side of member 24 closest to vanes 22 being coated with electron-emissive material 25. Positioned on the other side of member 24 is a heater structure 26. As shown here, heater structure 26 comprises a plurality of coils which may be connected either in series or in parallel to a heater voltage supply, said coils being surrounded by insulating material, such as, for example, Alundum. The heater structure 26 is surrounded by a metallic structure 27 attached, as by welding, to plate 24 which, as shown here, forms one wall of the structure 27. The entire cathode assembly 23 is insulatedly and rigidly supported with respect to anode members 22 by means of ceramic insulating members 28 attached, as by bonding, to the structure 27 and to the lower magnetron envelope member 17.

Cathode 23 is supplied with the required operated voltage by means of a hollow, metallic sleeve 34 attached, as by welding, to one end of the structure 27, sleeve 34 extending out through a hole in end member 19 and spaced from member 19. Sleeve 34 is insulatedly sealed to member 19 by means of a metallic cup member 35 attached, as by welding, to sleeve 34, cup member 35 being, in turn, bonded to a glass cylindrical sealing member 36 which is bonded to an annular protrusion on end plate 19.

One end of the heater structure 26 is connected to a wire lead-in member 37 which extends through cylinder 34 insulated therefrom by a glass bead 38 which seals the end of cylinder 34. The other end of the heater structure 26 is attached, as at 39, to the structure 27 and thereby to the cylinder 34. Thus, by the application of a potential between cylinder 34 and lead-in member 37, as by a battery 40, a heater current may be made to flow through the heater structure 26.

A magnetic field for the linear magnetron is provided by means of a permanent magnet 41, the poles of magnet 41 being positioned against the outer surfaces of side walls 15 and 16, respectively, at points adjacent the space between the anode members 22 and the cathode plate member 24. While any type of magnet may be used, the particular one shown here is made up of a series of laminations for ease of fabrication and magnetization.

If a voltage is applied between the cathode 23 and the anode members 22, for example, by means of a high voltage supply 42, and the cathode 23 is heated by the heater structure 26, electrons emitted from said cathode will be directed past the edges of anode members 22 setting up self-sustaining oscillations in the cavities defined by the anode vanes.

The resonant frequency of the linear magnetron is governed by the anode structure cavities, and should have a free space wave length substantially equal to twice the distance between adjacent disks 11 in the cylinder 10. If particles are introduced into one end of the cylinder 10 with an initial velocity of, for example, a million electron volts, they will have a velocity close to the velocity of light. Accordingly, if they are in phase with the fields in the toroidal cavities between the disks 11, they will be accelerated by these fields passing through each in turn until they reach the other end of cylinder 10, whereupon they may be utilized by being passed through an opening in the end plate 20, said opening being covered by a thin, metallic member 43 made, for example, of beryllium. The accelerated particle may be then used for any desired purpose, such as bombardment of a target.

While there has been illustrated here a one million volt electron gun 44 as a source of charged particles, namely, electrons, any desired high speed charged particle source could be utilized. Indeed, the particles could be introduced into the accelerator at lower velocities with the distances between adjacent disks 11, toward the end of cylinder 10 at which said particles were introduced, being made less than one-half a wave length in order to produce the desired phase locking between the charged particles and the accelerating fields. In the form shown here, adjacent toroidal cavities should be excited with fields which are one hundred and eighty degrees out of phase in order to produce the desired particle acceleration. In order to excite adjacent toroidal cavities out of phase, they should be fed through slots 13 which are coupled to cavities of the magnetron-anode structure which are separated by an even number of anode cavities of the anode structure, or by an odd number of anode members 22.

In order to adjust the system for optimum operation, suitable variable tuning devices may be incorporated therein, if desired. As illustrated herein, by way of example only, the tuning devices for the magnetron comprise metallic plungers 45 inserted through side walls 15 and 16 at intervals along the length of said walls. The inner ends of the plungers 45 are positioned adjacent the straps 29 such that movement of the ends

of said plungers toward or away from said straps will vary the capacitance between said straps, thereby tuning the frequency and relative phase of oscillations generated along the length of the anode structure.

As shown here, movement of the plungers is produced by rotation of bushings **46** surrounding reduced portions of said plungers, said bushings being threaded through walls **15** and **16**. The system is maintained vacuumtight at the tuning devices by means of bellows **47** sealed to plungers **45** and walls **15** and **16**, and surrounding said plungers. Adjustment of the accelerator cavities may be accomplished by tuning additional tuning plungers **45** extending through the walls of cylinder **10**, for example, two into each cavity thereof, as shown at **48**.

This completes the description of the specific embodiment of the invention illustrated herein. However, many modifications thereof will be apparent to persons skilled in the art without departing from the spirit and scope of this invention. For example, other types of integrated high-frequency generators, such as cavity klystrons, could be substituted for the linear magnetron. Other coupling structures could be used in place of slots **13** as, for example, loops or probes, and other configurations of the magnetron-anode cavities could be used. Accordingly, it is desired that this invention be not limited by the particular details of the embodiment described herein, except as defined by the appended claims.

What is claimed is:

1. An electron-discharge device comprising an evacuated envelope containing a charged particle accelerating structure, a source of alternating voltages coupled to said structure, said source comprising a linear magnetron, and a plurality of separate energy coupling means at a plurality of points spaced along said magnetron and said structure for coupling the output energy of said magnetron out of said magnetron and into said accelerating structure.

2. An electron-discharge device comprising an evacuated envelope containing a charged particle accelerating structure comprising a plurality of accelerating cavity resonators having a substantially linear unobstructed electron path therethrough, and a linear magnetron parallel to said accelerating structure and having coupling means coupled thereto, said coupling means being spaced along said magnetron at a plurality of points for coupling the output energy of said magnetron to said resonators, the phase of energy of adjacent said points being substantially out of phase with respect to each other.

3. An electron-discharge system comprising a charged particle accelerating structure, means adjacent said accelerating structure for introducing charged particles into said system to be accelerated by said accelerating structure, a magnetron, said magnetron comprising an anode structure having a plurality of anode vanes, alternate vanes being connected by conductive strapping, adjacent anode vanes, together with the space therebetween, defining anode cavities, and means coupling said accelerating structure to said anode structure, adjacent coupling means being separated by an odd number of anode vanes.

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References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
2,242,888	Hollmann	May 20, 1941
2,481,151	Powers	Sept. 6, 1949
2,543,082	Webster	Feb. 27, 1951
2,545,595	Alvarez	Mar. 20, 1951
2,556,978	Pierce	June 12, 1951
2,559,582	Bailey	July 10, 1951
2,582,186	Willshaw	Jan. 8, 1952