April 8, 1958 H. F. KAISER ET AL. 2,830,211

MICROTRON EXTRACTION TUBE

Filed July 10, 1957 2 Sheets-Sheet 1

FIG. 1

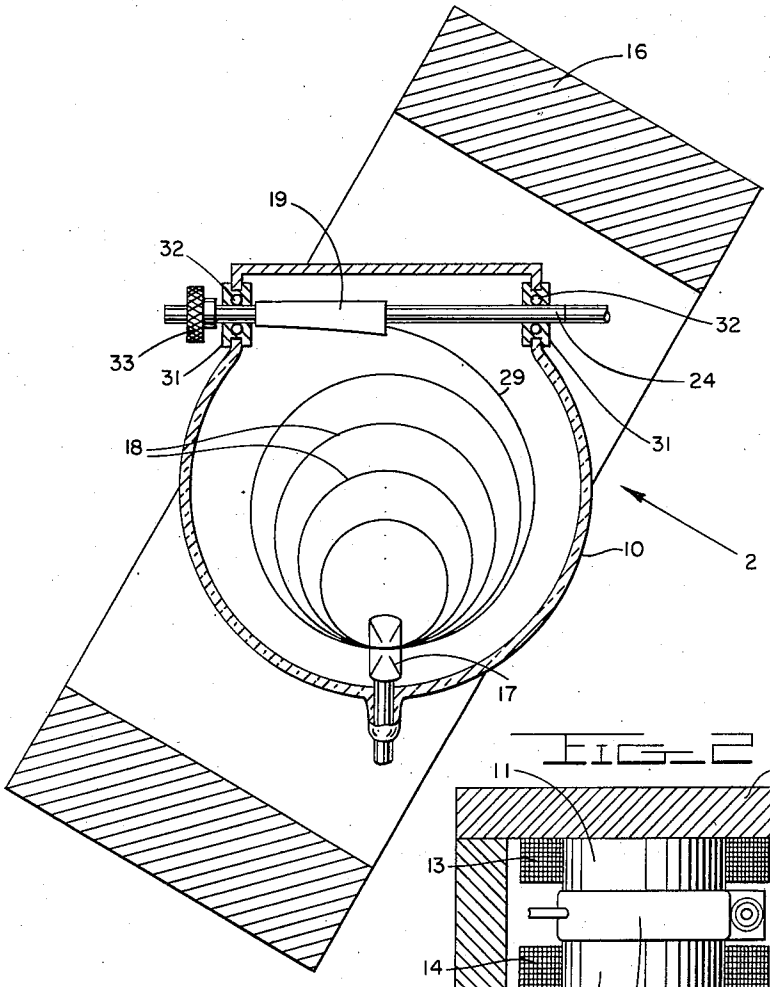


FIG. 2

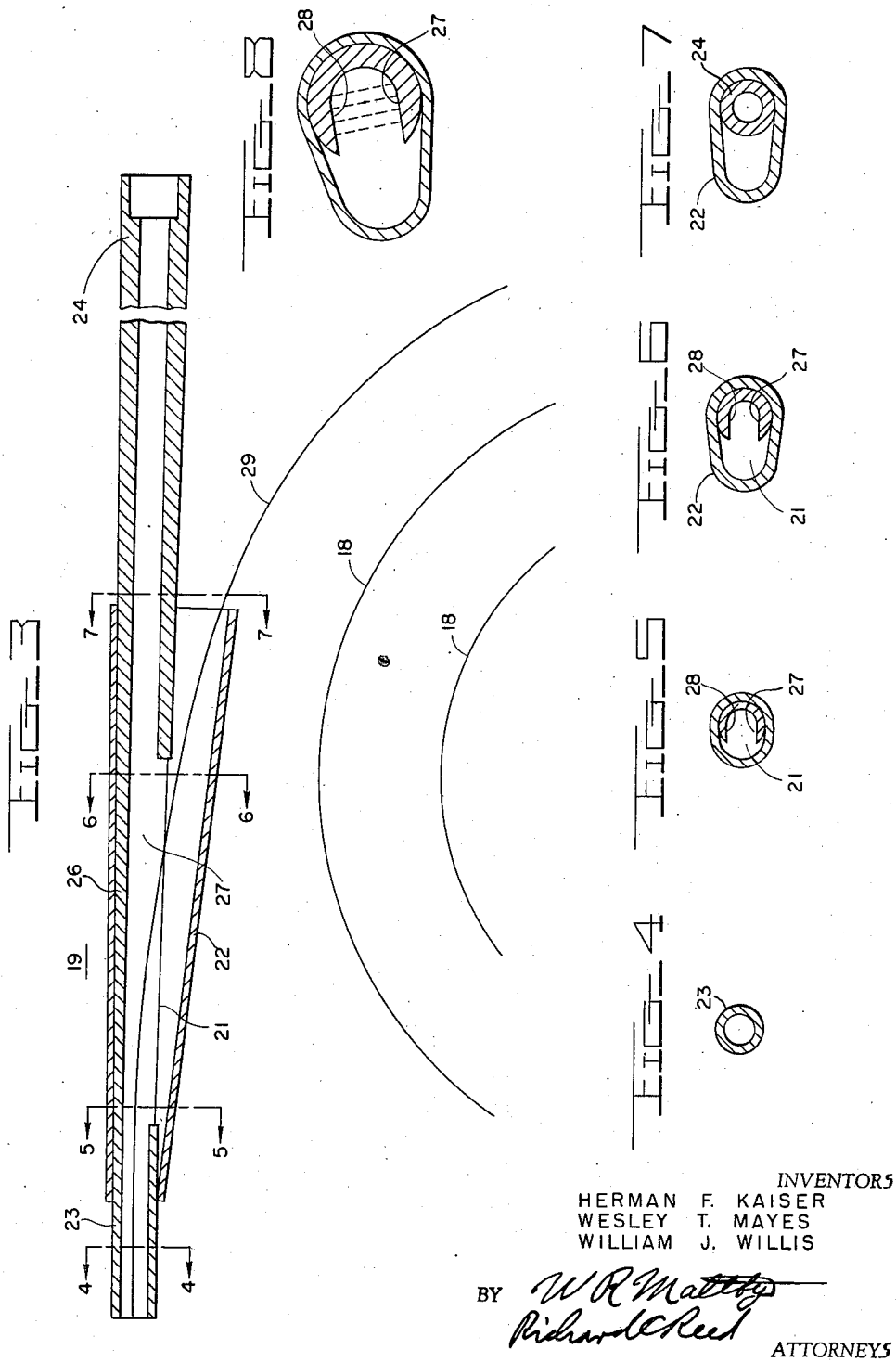
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MICROTRON EXTRACTION TUBE

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7 Claims. (Cl. 313—62)

(Granted under Title 35, U. S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

The present invention relates in general to charged particle accelerators and more particularly to the extraction of accelerated electrons from that type of electron accelerator or electron cyclotron known as a microtron.

As is well known, the microtron comprises in general an evacuated flat circular chamber traversed axially by a substantially uniform stationary magnetic guide field into which are injected bunches of electrons, by field emission from a cavity resonator excited by powerful pulses of radio frequency power, the bunches of electrons being repeatedly accelerated into orbits of increasing radius by repeated passage through the resonant cavity.

The present invention has to do with the extraction from a microtron of electrons from an outer orbit containing the higher accelerated electrons through an extraction tube to a point beyond the guide field or outside of the evacuated chamber for further control, observation or direct use.

Heretofore extraction of accelerated electrons from a microtron has been through the use of an extraction tube of low reluctance material in the form of a gradually tapered hollow cone tapering toward the ingress end positioned in the path of the orbit from which electrons are to be extracted.

Among some disadvantages of the tapered or conical extraction tube is the lack of magnetic shielding material near the point of entrance to the tube with insufficient reduction in field strength to permit the particles to assume a substantially straight path into and through the extraction tube.

An object of the invention is the provision in a microtron of an extraction tube so constructed and mounted in the microtron vacuum chamber as to permit the electrons to pass in a substantially straight path through the tube.

Another object is the provision of an extraction system for a particle accelerator affording fine adjustment of the path of particle travel through the extraction tube.

A further object is the provision of an extraction tube capable of permitting a mergence with the extracted beam, of an electron beam entering the tube from outside the microtron.

Various other objects and advantages of the invention will become apparent from a perusal of the following specification, having reference to the accompanying drawings in which:

Fig. 1 is a horizontal section through the mid plane of a microtron to which the invention is applied.

Fig. 2 is a side view on a reduced scale looking in the direction of the arrow in Fig. 1, partly in section.

Fig. 3 is a view of the extraction tube per se in longitudinal section.

Figs. 4, 5, 6 and 7 are, respectively, transverse sections on lines 4—4, 5—5, 6—6 and 7—7 of Fig. 3.

Fig. 8 is an enlargement of Fig. 6 showing deviation of the magnetic field in the channel.

Inasmuch as the mode of operation and general structure of the microtron are known in the art, it is believed sufficient here to illustrate and describe only those features concerned with the application of the present invention thereto.

A typical microtron with known form of extraction tube applied thereto has been described in an article by H. F. Kaiser and W. T. Mayes entitled "General Purpose X-band Laboratory Microtron" which appeared in the Review of Scientific Instruments, June 1955, pages 565–67.

Referring first to Figs. 1 and 2, here is shown in the one, a horizontal section and in the other, on a reduced scale, a side view, of the essential elements of a microtron having in combination therewith the improved extraction tube of the present invention. The usual circular vacuum chamber **10** is positioned between a pair of pole pieces **11**, **12** for directing a substantially uniform static magnetic guide field axially through the vacuum chamber. Energization of the magnetic field is effected by a set of energizing windings **13**, **14** surrounding the pole pieces, which windings are omitted from Fig. 1 for the sake of clearness. The magnetic circuit is completed in the usual manner through a suitable yoke structure **16**. Bunches of electrons are injected into the vacuum chamber **10** in known manner by a high voltage cavity resonator **17** located near one side of the chamber, and excited at radio frequency say in the S-band or X-band. Electrons extracted from the metal of the resonator gap element by electric field emission, a bunch of electrons for each resonator period, are ejected into the magnetic guide field to be guided through circular orbits substantially in a common orbital plane back through the resonator gap for repeated accelerations into successive circular orbits **18** of increasing radius cotangent at the resonator gap.

For improved efficiency and facility in extraction of accelerated electrons from the given outer orbit applicants provide the novel extraction tube constructed as shown in detail in Fig. 3 and mounted in the vacuum chamber as shown in Fig. 1. Referring to Figs. 3–7, the extraction tube **19**, in order to function as a magnetic shielded conduit and outer field diminishing element, is constructed of high permeability, magnetic material such as iron, and in the form of a straight tube with a lateral ingress opening **21** shielded by a magnetic shielding hood **22** of the same or similar material as that of the straight portion. The end portions **23** and **24** are of annular cross section as indicated in the sectional views of Figs. 4 and 7, while the central portion **26** with the lateral opening **21** is of channel section with parallel inner side walls **27**, **28** as indicated in Figs. 5 and 6. To increase the volume of iron in the vicinity of the lateral ingress opening **21** of the extraction tube with consequent reduction of guide field intensity, the walls of the tube are increased slightly in thickness from left to right as shown in Fig. 3. To further control the transition zone from full microtron field to internal shielded field, and provide a shielded passageway for electrons into the opening **21**, a shielding hood **22** is provided in the form of a hollow relatively thin walled cone of oval section fitted over the exit half of the extraction tube with its flared end extended inwardly of the vacuum chamber overlying and spaced away from the lateral ingress opening **21**, with the ingress opening facing toward the orbital centers to provide a passageway for electrons into the ingress opening **21** shielded by the hood.

Because of the presence of the low reluctance material constituting the extraction tube and the conical hood element **22**, the magnetic field between an outer orbit **29**

and the ingress opening **21** is gradually diminished as the extraction tube is approached. As the path of an electron must satisfy the equation

$$\frac{mv^2}{r}=\frac{Hev}{c}$$

where m is the mass, v the velocity, r the radius, H the magnetic field strength, e the charge on the particle and c the velocity of light, the equation for the radius is:

$$r=\frac{mvc}{He}$$

The second equation shows that at a given point in the orbit the instantaneous radius of curvature of the orbit is inversely proportional to the strength H of the transverse magnetic guide field at the given point. Since the momentum (mv) is a constant of the motion, and e and c are natural constants (charge on electron and velocity of light). Thus it will be seen that as H decreases the orbital radius increases continuously so that the direction of travel of the electrons gradually becomes a straight line motion to bring about an asymptotic approach to parallelism with the tube axis. It may be noted that the hood **22** with its possible design of shielding thickness varying along a given ejection trajectory allows the shape of this ejection trajectory to be empirically altered into a variety of curve shapes particularly those which approach the final direction in an asymptotic manner.

Extension of the extraction tube structure completely across the field region of the microtron through the vacuum chamber to points in vacuum but outside the vacuum chamber **10**, provides a shielded passageway for electrons ejected into the tube from another source outside the microtron vacuum chamber for mergence with those extracted from the microtron. Where such enrichment of the electron stream from outside is not required, the end portion **24** of the tube may be closed off by a suitable vacuum seal closure.

Vertical focusing of a kind for diverting the beam of electrons in its passage through the tube for purpose of adjustment, is obtained by mounting the tube in the walls of the vacuum chamber for slight rotational adjustment about its axis with the channel facing in the general direction of the orbit centers. This is accomplished by the use of suitable bearing blocks **31** with vacuum seals in the form of O-rings **32**. With this construction, and with the parallel sides of the channel section lying normal to or nearly normal to the direction of the guide field, such of the magnetic guide field as penetrates the tube across the space within the channel, tends to maintain a direction normal to the parallel sides even though the tube may be slightly rotated about its axis to move the sides out of perpendicularity with the magnetic field lines. Rotational adjustment of the tube may be effected by any known or other suitable means as by the knurled collar **33** mounted on an extension of the extraction tube outside the vacuum chamber. However, it will be understood that where desirable the means for rotational adjustment of the tube may take the form of any known or other suitable remote control system for rotatable adjustment of the tube about its axis. Thus, as shown in Fig. 8, with slight rotation of the tube about its axis, such weak magnetic field as exists across the space between the parallel sides of the channel may be warped or canted to impart a slight rotation of the field vector away from the vertical and cause a vertical force component raising or lowering the extracted electron beam. It will be understood that the terms "vertical" and "horizontal" are here used to indicate relative direction and are not to be construed as limiting the position of a part independently of other parts.

While a specific embodiment of the invention has herein been described for the sake of disclosure, it is to be understood that the invention contemplates all such

variations and modifications thereof as fall fairly within the scope of the appended claims.

What is claimed is:

1. In a microtron having an evacuated chamber in which electrons are accelerated through a static magnetic guide field to travel in orbits increasing in radius with increase in velocity and energy, the combination of an extraction tube of low reluctance material extending from a point of egress beyond the guide field into the guide field along the orbital plane near an outer orbit having a lateral ingress opening facing in a direction to receive electrons from said outer orbit, and a conical hood member of low reluctance material fitted over the extraction tube with its flared end extending into the guide field over said ingress opening to provide a shielded passage for electrons into the ingress opening of the tube, said extraction tube and hood member being constructed to provide a volume of the low reluctance material near the ingress opening greater than that near the point of egress, the reduction in volume being gradual whereby the volume of magnetic material present within the guide field near the ingress opening will be sufficient to gradually diminish the field strength between an outer orbit and the ingress opening as the ingress opening is approached and the field within the tube gradually reduced to cause the trajectory of the electrons to approach parallelism with the axis of the tube in an asymptotic manner.

2. In a microtron having an evacuated chamber in which electrons are accelerated through a static magnetic guide field to travel in orbits increasing in radius with increase in velocity and energy, the combination of an extraction tube of low reluctance material extending from a point of egress beyond the guide field into the guide field along the orbital plane near an outer orbit, said tube having a lateral ingress opening facing in a direction to receive electrons from said outer orbit and a portion of its interior formed with a pair of opposite flat parallel walls lying normal to the magnetic guide field, a conical hood member of low reluctance material fitted over the tube with its flared end extending into the guide field over said ingress opening and spaced therefrom to provide a shielded passage for electrons into the ingress opening of the tube, and means mounting the tube for rotational adjustment about its axis whereby such magnetic lines of force as traverse the tube between said parallel side walls may be canted away from the vertical to deflect up or down an electron beam passing through the tube.

3. In a microtron having an evacuated chamber in which electrons are accelerated through a static vertical magnetic guide field to travel substantially in a common horizontal plane in orbits increasing in radius with increase in velocity and energy, the combination of an extraction tube of low reluctance material extending from a point outside the vacuum chamber into the vacuum chamber through the guide field along the orbital plane near an outer orbit and having a lateral entrance portion facing in a direction to receive electrons from an outer orbit, and a conical hood member fitted over the extraction tube with its flared end extending inwardly of the vacuum chamber over said lateral entrance portion to provide a shielding passage for electrons into the lateral entrance portion of the tube, said extraction tube extending with closed side walls from the lateral entrance portion through the guide field in a direction opposite from the first mentioned outside point to a second point outside the evacuated chamber providing a shielded passage for a merging stream of electrons from outside the vacuum chamber.

4. In a microtron having an evacuated chamber in which electrons are accelerated through a static vertical magnetic guide field to travel substantially in a common horizontal plane in orbits increasing in radius with increase in velocity and energy, the combination of an

extraction tube of low reluctance material extending from a point outside the vacuum chamber into the vacuum chamber through the guide field along the orbital plane near an outer orbit and having a lateral entrance portion in the form of a channel with parallel sides normal to the magnetic guide field, and means mounting the tube for rotational adjustment about its axis whereby such magnetic lines of force as traverse the channel section may be canted away from the vertical to deflect up or down an electron beam passing through the tube.

5. In a microtron having an evacuated chamber in which electrons are accelerated through a static magnetic guide field to travel in orbits increasing in radius with increase in velocity and energy the combination of an extraction tube of low reluctance material extending from a point of egress outside the vacuum chamber into the vacuum chamber through the guide field with an ingress opening near an outer orbit, said extraction tube having a wall thickness near the ingress opening greater than that of the remainder of the tube extending toward the point of egress.

6. In a microtron having an evacuated chamber in which electrons are accelerated through a static magnetic field to travel in orbits increasing in radius with increase in velocity and energy, the combination of an extraction tube of low reluctance material extending from a point of egress beyond the guide field into the guide field with an ingress opening near an outer orbit, said extraction tube being constructed to provide a volume

of the low reluctance material near the ingress opening greater than the volume of material near the point of egress, the reduction in volume being gradual whereby the volume of magnetic material present within the guide field near the ingress opening will be sufficient to gradually diminish the magnetic field between an outer orbit and the ingress opening as the ingress opening is approached and the field within the tube gradually reduced to cause the trajectory of the electrons to approach the axis of the tube in an asymptotic manner.

7. In a microtron having an evacuated chamber in which electrons are accelerated through a static vertical magnetic guide field to travel substantially in a common horizontal plane in orbits increasing in radius with increase in velocity and energy, the combination of an extraction tube of low reluctance material extending from a point outside the vacuum chamber into the vacuum chamber through the guide field along the orbital plane near an outer orbit with an ingress opening near such outer orbit, said ejection tube having a portion of its interior formed with a pair of opposed flat parallel walls lying normal to the magnetic guide field, and means mounting the tube for rotational adjustment about its axis whereby such magnetic lines of force as traverse the tube between said parallel side walls may be canted away from the vertical to deflect up or down an electron beam passing through the tube.

No references cited.