APPARATUS AND METHOD FOR SELECTIVELY PRODUCING HIGH CURRENT OF HIGH ENERGY BEAMS OF ACCELERATED CHARGED PARTICLES

Filed Sept. 28, 1964

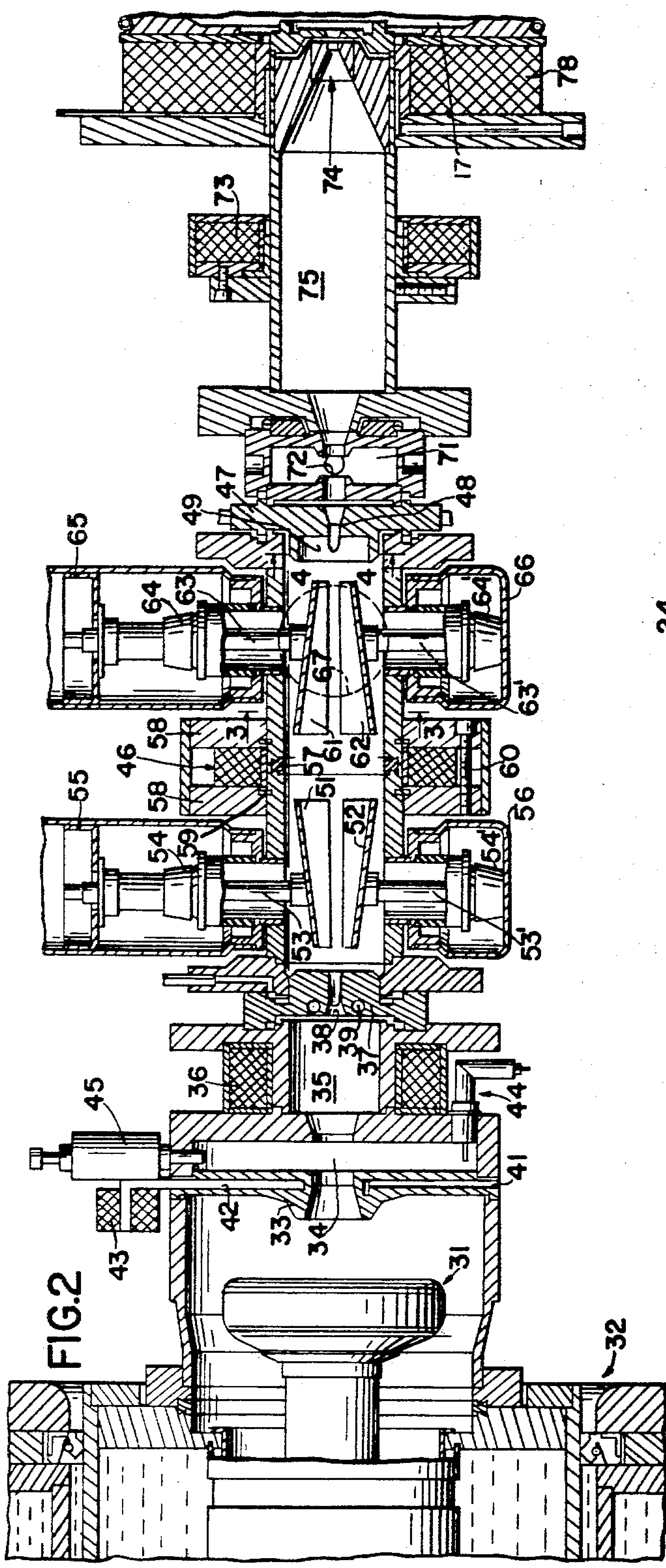

FIG.2

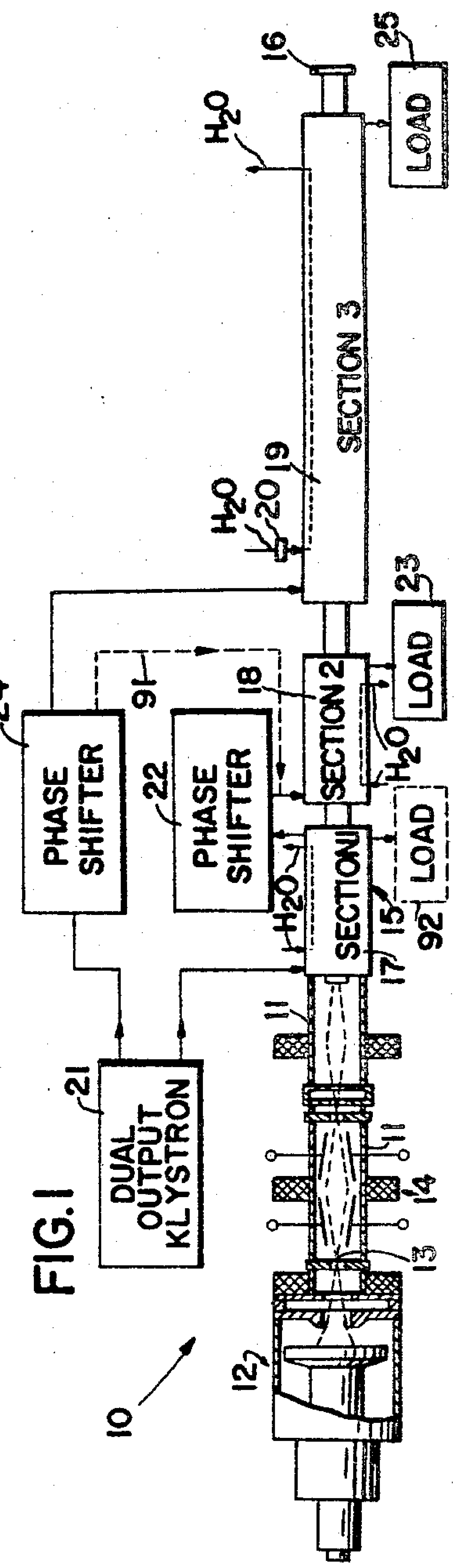

FIG.1

INVENTOR
JACOB HAIMSON

BY [signature]
ATTORNEY

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FIG. 4

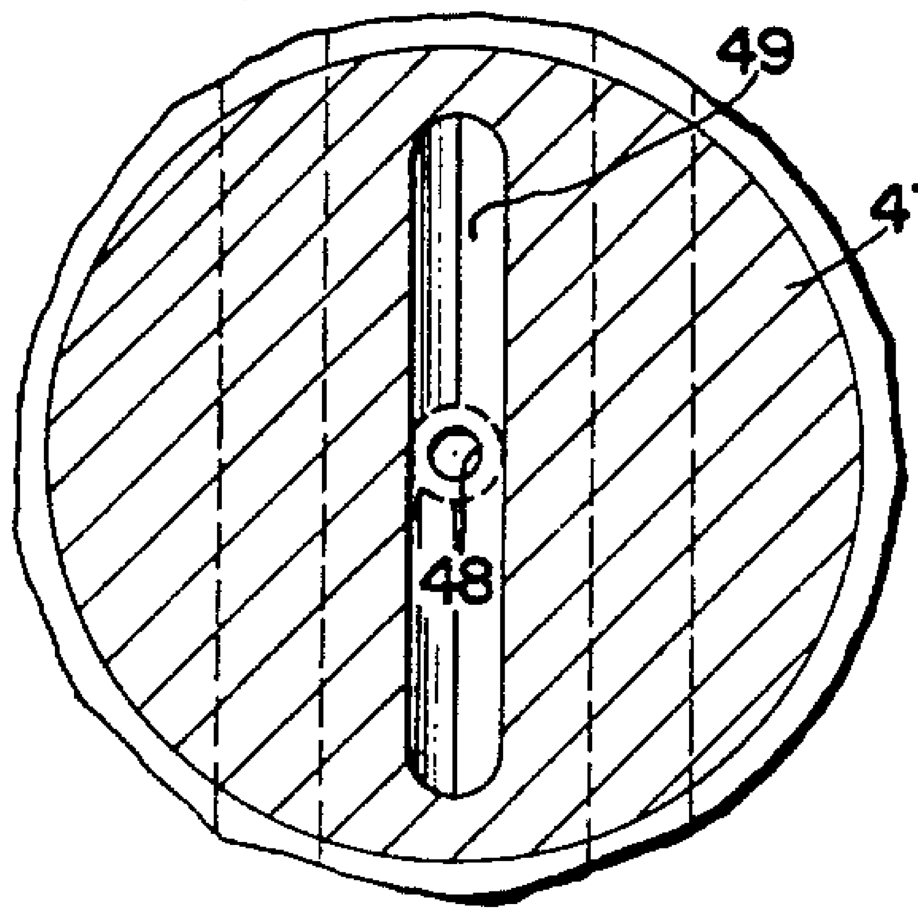


FIG. 5

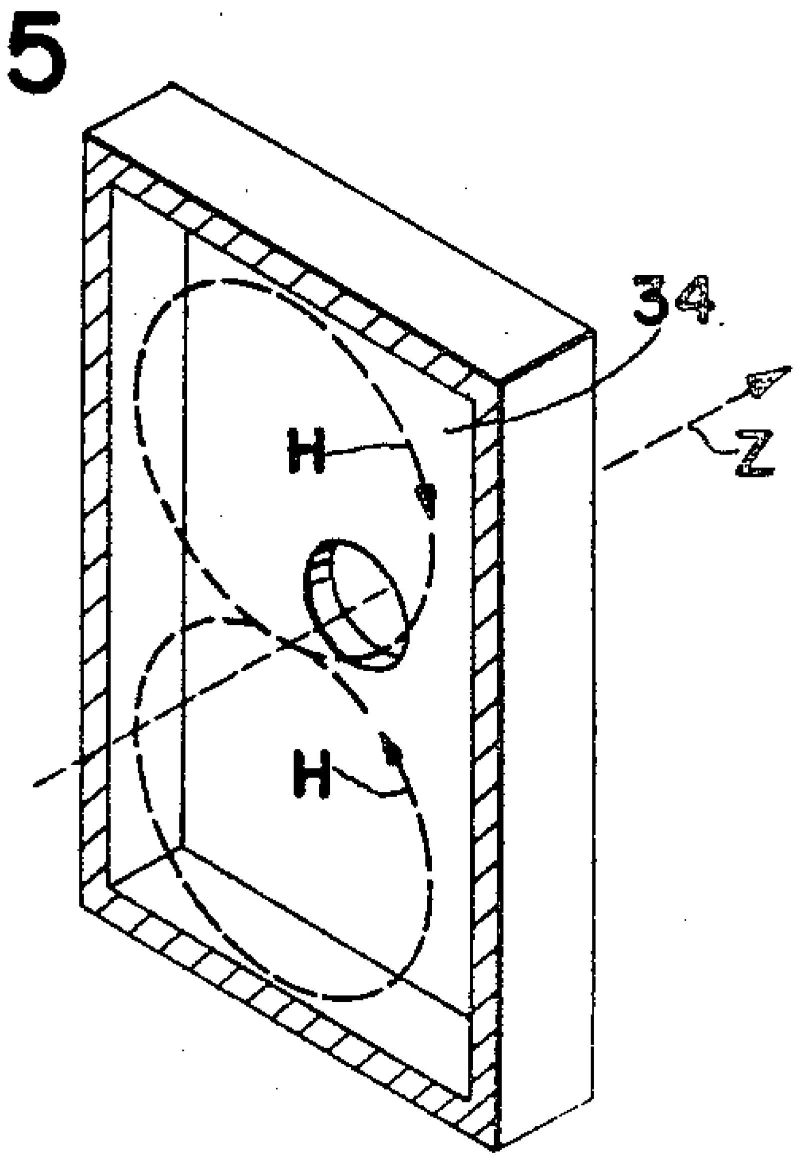


FIG. 7

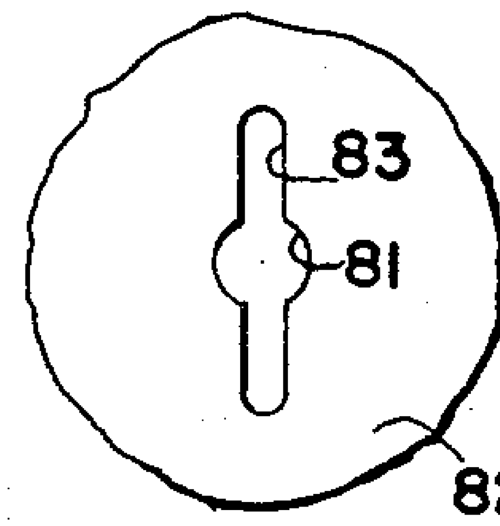


FIG. 6

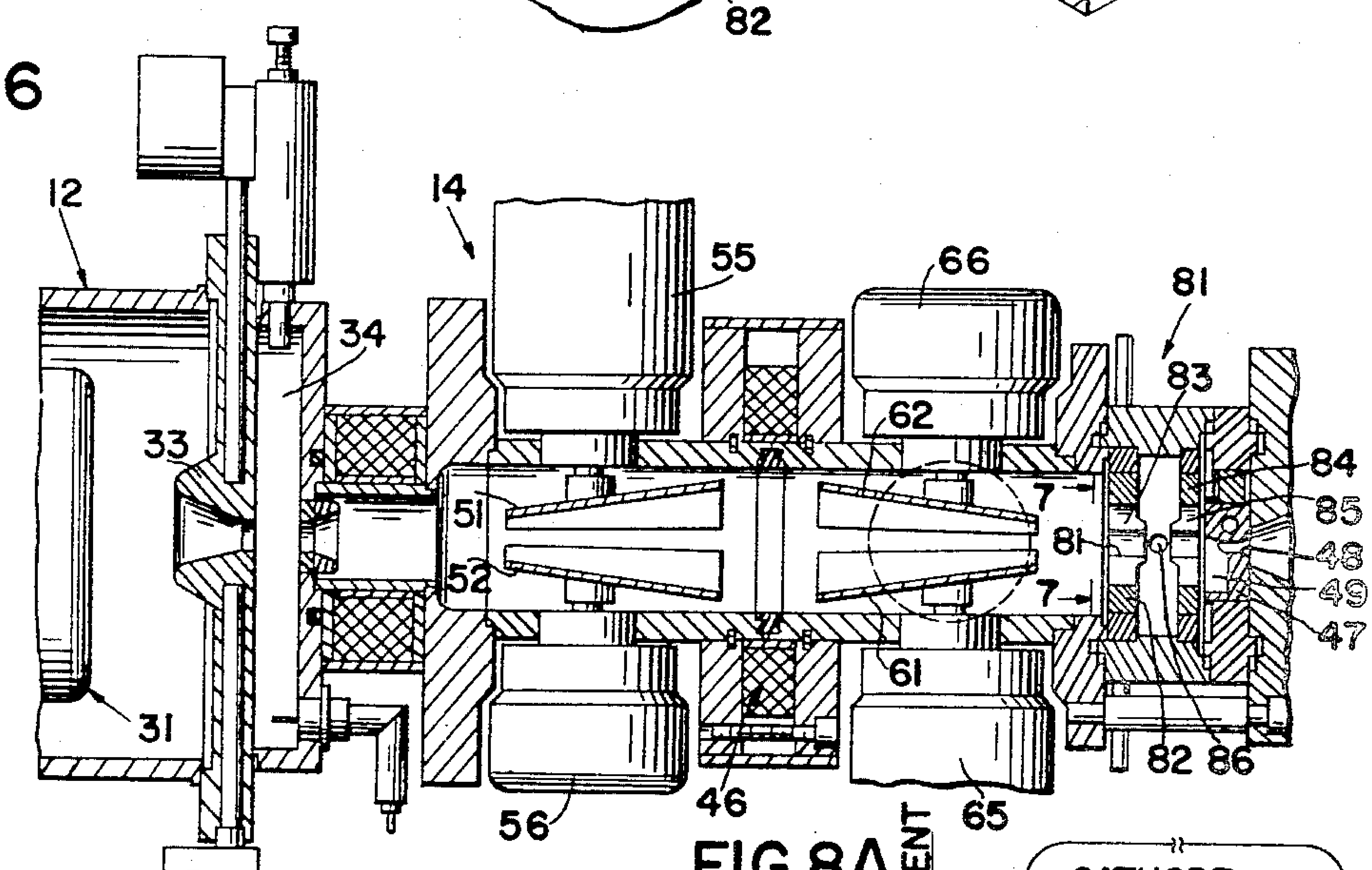


FIG. 8A

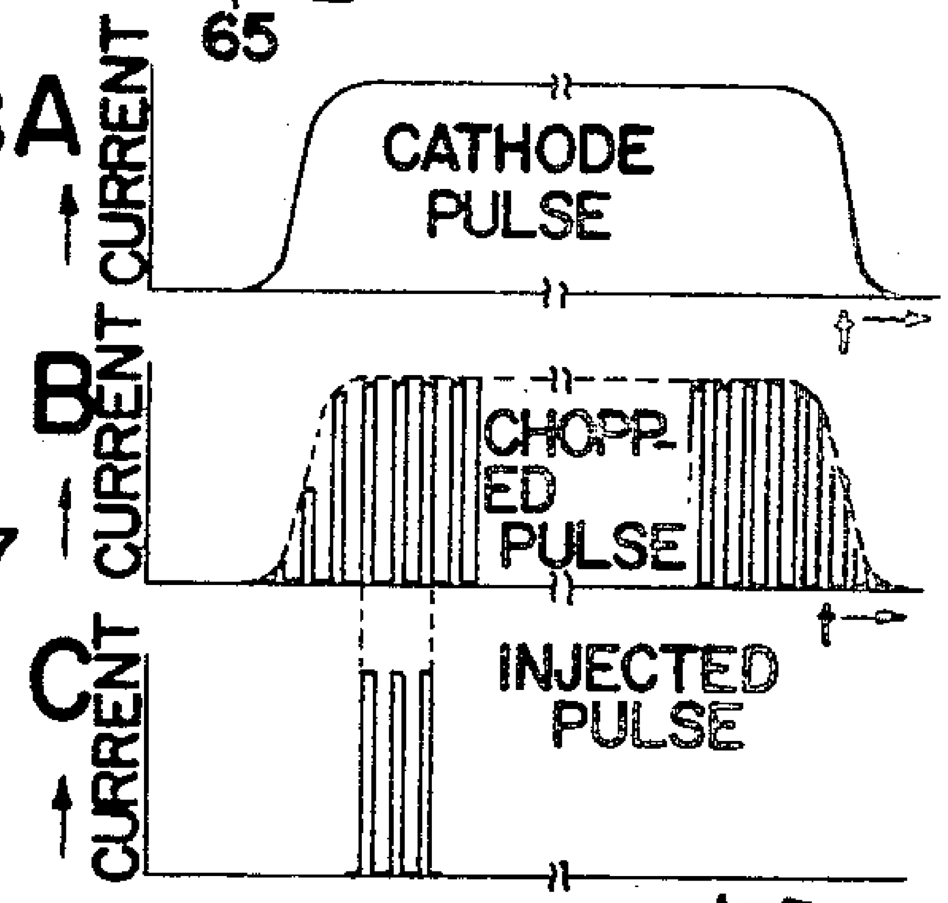
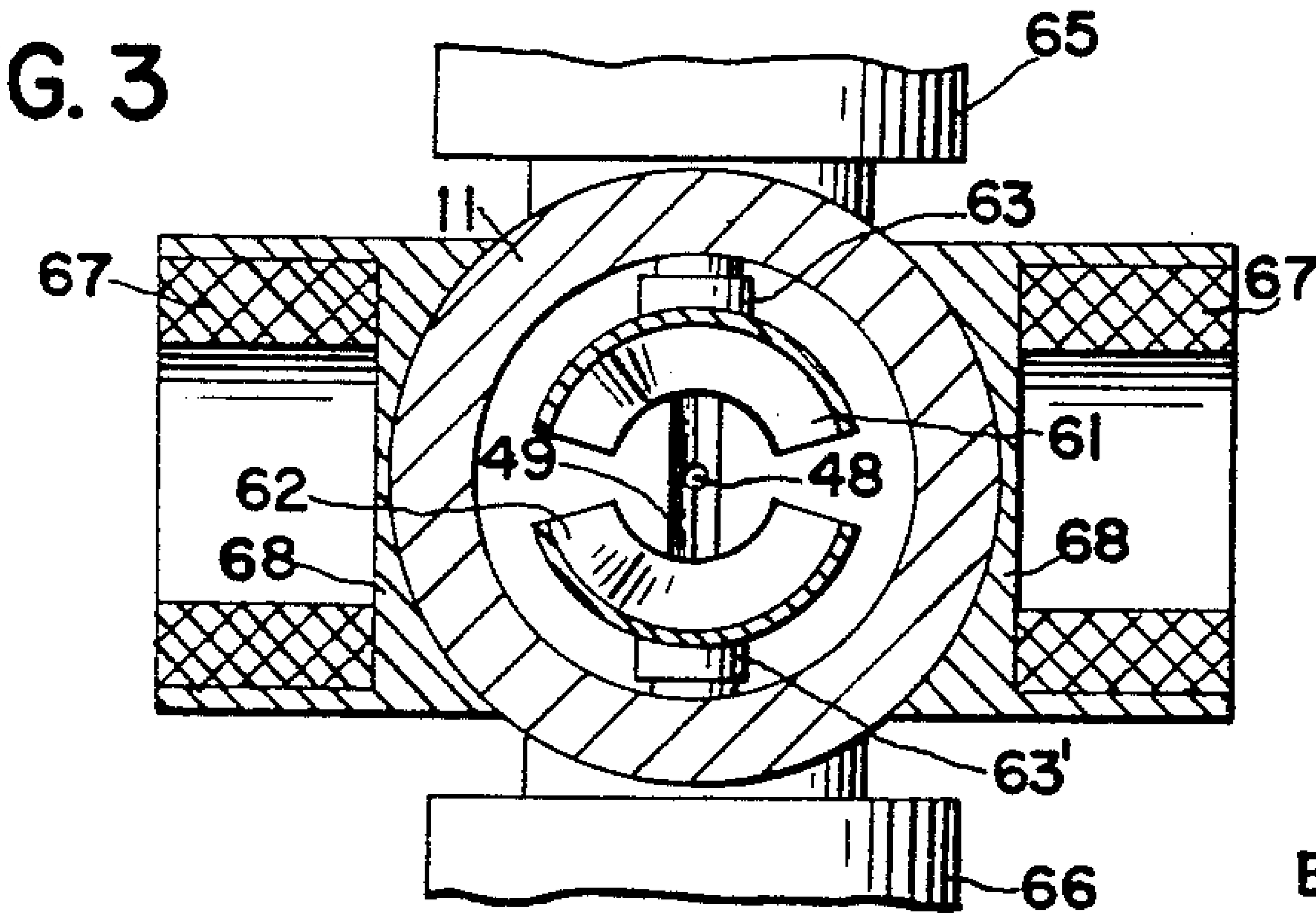


FIG. 3



INVENTOR
JACOB HAIMSON

BY [signature]

ATTORNEY

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APPARATUS AND METHOD FOR SELECTIVELY PRODUCING HIGH CURRENT OF HIGH ENERGY BEAMS OF ACCELERATED CHARGED PARTICLES

Jacob Haimson, East Palo Alto, Calif., assignor to Varian Associates, Palo Alto, Calif., a corporation of California

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8 Claims. (Cl. 328—233)

ABSTRACT OF THE DISCLOSURE

In a linear particle accelerator having at least three accelerating sections, a dual output klystron provides input power into the first section and into the second or third sections depending on whether a high current or high energy output is desired. In the high current mode, the input power is coupled into the second section through a phase shifting switching circuit with the residual energy remaining at the output of the first section being dissipated in an external load. In the high energy mode, the phase shifting switching circuit couples the input power into the third section with the residual energy remaining at the output of the first section being coupled through a second phase shifting switching circuit into the second section instead of the load. A heater is provided in the cooling lines of the third section to control the temperature and electrically decouple the third section during high current operation in rder to effect a zero net energy transfer from the particle beam to the waveguide section as the beam passes therethrough.

The present invention relates in general to particle accelerators and more particularly to multiple section linear particle accelerators.

In the acceleration of particles such as, for example, electrons and positrons to high energy in a linear particle accelerator, the ultimate beam energy and beam current are dependent upon the impedance and length of the accelerating waveguide and the applied RF power. Alternately, the length and impedance characteristics of the waveguide structures are dependent upon the required beam energy and the efficiency of conversion from RF power to particle beam power. Also because the input RF power is limited from each klystron RF power source to, on the order of 20–30 mw., high power beam performance requires multiple klystrons and accelerating waveguide sections. It is often desired to utilize the particle beam over a wide variation of current and energy levels at the end of the several accelerator sections.

The object of the present invention is to provide a multiple section linear accelerator that will produce multiple performance specifications without changing the parameters of the injection and bunching systems of the accelerator.

One aspect of the present invention is the provision of a dual purpose accelerating structure which can be adjusted for multiple performance specifications such as either high current, medium energy output or high energy medium current output. In accordance with this aspect of the present invention a series of at least three accelerating sections are provided with means for directing input power into the first section and other input power either into the second section for high current operation or into the third section for high energy output in which case means are provided for coupling the energy remaining at the end of the first section into the second section. For high current operation of the accelerating structure provision is made for either displacing or decoupling the third section for utilization of the

particle beam current and energy emanating from the second section. This accelerator construction permits the trapping and bunching electric fields which vary from cavity to cavity in the initial accelerating waveguide, to be utilized and maintained for both high current and high energy operation.

Another feature of the present invention is provision for decoupling one section of a plurality of accelerating waveguide sections from the particle beam transmitted therethrough by changing the operating temperature of the section thereby to change the dimensions and thus the phase of the traveling RF wave with respect to the beam particle bunches in such a manner that there is a zero net energy transfer from the particle beam to the waveguide section upon passage therethrough.

These and other features and advantages of the present invention will be more apparent upon a perusal of the following specification taken in connection with the accompanying drawings wherein:

FIG. 1 is a schematic view partially broken away of a linear accelerator incorporating features of the present invention;

FIG. 2 is an enlarged elevational sectional view of a portion of the structure schematically illustrated in FIG. 1;

FIG. 3 is a sectional view of a portion of the structure shown in FIG. 2 taken along line 3—3 in the direction of the arrows;

FIG. 4 is an enlarged sectional view of a portion of a structure shown in FIG. 2 taken along line 4—4 in the direction of the arrows;

FIG. 5 is an enlarged perspective view partially in section schematically illustrating a main chopping cavity in accordance with the present invention;

FIG. 6 is a sectional view of an alternative structure in accordance with the present invention;

FIG. 7 is a sectional view of a portion of the structure shown in FIG. 6 taken along line 7—7 in the direction of the arrows; and

FIGS. 8A–8C are graphs of current versus time for particles in certain portions of a machine employing the present invention.

The present invention is directed primarily to a pulsing apparatus which can be utilized in a particle accelerator such as, for example, an electron linear accelerator. While the invention will be described hereinafter with particular reference to an electron linear accelerator it can be utilized with other pulse particle utilizing apparatus such as, for example, positron accelerating structures.

Referring now to the drawings, with particular reference to FIG. 1, there is schematically illustrated a particle accelerator **10** which includes an elongate vacuum envelope **11** with a beam generating assembly **12** for generating and directing a particle beam **13** longitudinally of the envelope **11**. A beam deflecting and injecting assembly **14** is disposed along the envelope **11** between the beam generating assembly **12** and a particle accelerating wave guide **15** which is provided at its output end with an output window **16** through which a pulse of electrons which have been accelerated to relativistic velocities can be passed for performing sophisticated nuclear experiments or for direction onto a target electrode for generating other radiation such as, for example, X-rays.

The accelerating wave guide **15** includes a plurality of wave beam interaction structure **17**, **18** and **19** such as, for example, apertured disc-loaded wave guide for transferring energy from radio frequency electromagnetic waves to charged particles such as, for example, electrons passing therethrough for accelerating the electrons to relativistic velocities. The accelerating wave guide **15** is energized by a high power RF source such as, for example, a dual output klystron tube **21** in which the microwave energy from one of the output arms is fed into section **17** for transmission therethrough, through a phase shifter **22** and through section **18** for interaction with a pulse of charged particles directed therethrough from the beam generating assembly **12**. The accelerating sections **17, 18** and **19** are fluid-cooled such as, for example, by water for absorption of the heat dissipated in the waveguide by the RF power, and residual RF power remaining at the end of section **18** can be coupled to a load **23**. RF energy from the other output arm of the klystron **21** is coupled through a phase shifter **24** into the accelerating section **19** in proper phase relation with respect to the partially accelerated pulse of charged particles to continue accelerating the particles until they reach the end of the accelerating section **19** and are passed through the window **16** or into other apparatus for utilization. Residual RF power at the output end of accelerating section **19** can be passed into an external load **25**. The fluid-cooling assembly for the third accelerating section **19** is provided with a heater **20** for changing the temperature of the cooling fluid, thereby to decouple the section **19** from the particle beam.

The beam generating assembly **12** and the beam deflecting and injection assembly **14** are constructed for producing pulses of charged particles having a pulse length continuously variable down to a minute fraction of a second.

Referring now to FIG. 2 which illustrates an enlarged view of assemblies **12** and **13**, the beam generating assembly **12** includes a cathode and focus electrode assembly **31** which is mounted at the one end of the envelope **11** and whichd uring operation is positioned in an electrical insulating oil bath **32**. Spaced along the axis of the particle accelerator **10** from the cathode of focus electrode assembly **31** is an apertured anode **33** which is followed by a beam chopping cavity resonator **34** which will be described in greater detail below with reference to FIG. 5.

A drift space **35** is positioned along the beam path following the cavity resonator **34** and is surrounded by a magnetic lens **36** for focussing the particle beam **13** onto a collector **37** or through a collimating aperture **38** in the collector **37** for passing short pulses of charged particles through the collimating aperture **38** into the beam deflecting and injection assembly **14**. The collector **37** and the anode **33** are provided with water-cooling channels **39** and **41** respectively for passing cooling fluid through these respective electrodes to cool the electrodes which are heated due to interception of the charged particles.

A plurality of separate beam steering probes are provided around the aperture in the anode **33** and include a steering rod **42** of magnetic material which projects radially outwardly of the anode **33** with its exterior end surrounded by a coil **43** for changing the magnetic field established at the interior ends of the steering rods **42**.

A coupling loop **44** is provided for coupling RF energy into the cavity resonator **34** which can be tuned to the desired operating electromagnetic mode by means of the tuner schematically illustrated at **45**.

The beam deflection assembly **14** spaced axially down the envelope **11** from the collector **37** includes a focusing lens **46** such as, for example, a thin magnetic lens coil for focusing the diverging pulsed electron beam **13** onto a subsequently positioned collecting electrode **47** or through an axially aligned collimating aperture **48** in the collector **47**. A first pair of deflection plates **51** and **52** is located on opposite sides of the beam path between the collector **37** and the lens **46** for deflecting the pulsed electron beam **13** from a position in which the beam impinges on the collector **47** to a position for passage through the collimating aperture **48**. The collector **47** is provided with an energy distributing slot **49** (see FIG. 4), V-shaped in cross-section, extending across the collector on opposite sides of the collimating aperture **48** for collecting the beam focused thereinto over a large surface area. The pulse of charged particles is swept longitudinally of the slot **49** during operation of the deflecting assembly as described in detail below. The collector **37** is provided with a similar energy distributing slot along which the pulse of charged particles is swept by the fields in the beam chopping cavity resonator **34**.

Each of the deflection plates **51** and **52** is semi-cylindrical in form tapering outwardly in the direction of beam travel and is supported on one end of a conducting rod **53**, the other end of which is supported in a vacuum seal assembly **54** located in the envelope **11**. The conducting rod **53** which supports the deflection plate **51** is connected to a thyratron **55** which is coaxially supported with respect to the vacuum seal **54**. The conducting rod **53'** which supports the deflection plate **52** is connected to ground via a metallic cup-shaped member **56** which surrounds the vacuum seal **54'** and is electrically connected to the body of the metallic envelope **11**.

A second pair of deflection plates **61** and **62** is located between the lens **46** and the collector **47** for deflecting the electron beam from the position in which it passes through the collimating aperture **48** to a position for ampringement on the collector **47**. These plates **61** and **62** are shaped similarly to plates **51** and **52** but tapered inwardly toward the axis in the direction from the lens **46** to the collector **47**. Plate **61** is connected via connecting support rod **63**, through a vacuum seal **64** to a coxially mounted thyratron **65** while plate **62** is connected via support rod **63'**, through vacuum seal **64'** and via a metallic cup-shaped member **66** to the envelope **11** and ground. The second pair of deflection plates **61** and **62** is rotated (not shown) about the envelope **11** axis with respect to the pair of plates **51** and **52** to allow for rotation imparted to the beam in passing through the lens **46**, and this rotation is accomplished by a rotatable vacuum joint in the envelope at the lens **46**. This vacuum joint includes a metal gasket vacuum seal **57** which is held together by a pair of rotatable flanges **58** rotatably secured on the envelope **11** on opposite sides of the magnetic lens **46** by retaining rings **59** and held together by a plurality of bolts **60**.

A magnetic bias field is produced in the region between the second pair of plates **61** and **62** by a pair of electric coils **67** provided with end pole pieces **68** located against the exterior of the envelope **11** midway between the deflection plates **61** and **62** as shown in greater detail in FIG. 3. The magnetic bias field produced by the coils **68** counterbalances the electric field between plates **61** and **62** so that for operation of the deflection assembly as described in greater detail below plate **62** can be grounded, thereby avoiding problems of voltage variation on plate **62** and consequent variation in electric field strength between the plates due to interception of charged particles on plate **62**.

The electric field between each pair of deflection plates can be separately controlled as will be described in greater detail below for deflecting the electron beam between the position off the axis of the envelope **11** for collection on collector **47** to a position on the axis of the envelope **11** for passage through the collimating aperture **48**. In this manner an easily adjusted short pulse of electrons can be passed through the collimator **48** into a prebuncher cavity **71** in which RF fields are established such as, for example, by an RF signal introduced thereinto via an input coupling loop **72**. The bunched short pulse of charged particles emanating from the prebunching cavity **71** is focused to a small diameter by means of, for example, a thin magnetic lens coil **73** and directed into the input end of the first accelerator section **17** through a collimating aperture **74**. The focusing coil **73** is axially slidable along the length of a drift space **75** between the prebunching cavity **71** and the collimating aperture **74** for producing an optimum focus of the pulse of charged particles into the accelerating structure.

Referring now to FIG. 5, the chopping cavity **34** has oscillating magnetic fields across the beam path through the center of the cavity and this region of the cavity is free from counterbalancing deflecting electric fields. As shown, the cavity resonator **34** is a rectangular cavity operating in the TE_{102} mode. The electric fields associated with the deflecting magnetic fields illustrated in FIG. 5 are threaded through the magnetic fields and rather than existing at the center of the cavity where the beam path lies are distributed such as to provide a peak field between the beam hole and the cavity end walls. Alternatively, the cavity resonator can be circular resonator operating in the TM_{110} mode for producing the same particle deflection effects as the rectangular cavity described above. Here again in the circular TM_{110} cavity resonator the oscillating magnetic fields arranged transverse to the cavity axis in the pattern as shown in FIG. 5 for a rectangular cavity are concentrated on the beam axis of the accelerator with the electric fields concentrated remote therefrom. With the particle beam directed through the cavity resonator centrally thereof, the particle beam is subjected to deflecting magnetic fields without being subjected to compensating or counterbalancing deflecting electric fields.

Chopping cavities operating in higher order modes such as, for example, rectangular TE_{10n} and circular TM_{1m0}, where n and m are integers and $n \geq 2$ can be utilized so long as the relationship of beam path to the magnetic and electric fields is similar as for the primary modes described above.

Operation of the method and apparatus in accordance with the present invention will be described with a typical operating example. A pulsed electron beam is produced in the beam generating assembly **12** having a pulse duration of approximately several microseconds, a rise time on the order of tenths of microseconds, and a peak beam current on the order of approximately 4 amps, such as illustrated schematically in FIG. 8A. The beam steering coils are properly adjusted to focus the beam pulse into the V-shaped groove in the collector **37** and biased to one side of the collimating aperture **38** so that during deflection in the chopper cavity and at only one end of the chopper deflection pattern the particle pulse is directed through the collimating aperture **38** for transmission into the deflection assembly **14**, i.e., only one burst of particles per RF cycle. When the beam pulse is not biased to one side of the collimating aperture two particle bursts are transmitted per cycle and, for example, when injected into a linear accelerator only one burst will be accepted; the other (displaced 180° in phase) will be automatically rejected by the reversed high electric field in the accelerator. An RF signal such as, for example of S-band frequency is fed into the chopper cavity to sweep the pulsed particle beam across the collector **37** so that only a portion of the particle pulse is passed through the collimating aperture **38** into the deflecting assembly each cycle of the oscillating electromagnetic fields within the chopper cavity **34**, as illustrated schematically in FIG. 8B. The duration of the cycle in the chopping cavity is, for this example, about ⅓ nanosecond, and the duration of each individual burst of particles passed from the chopping cavity into the deflection assembly depends upon the ratio of beam diameter to collimator aperture and the magnitude of scan in the chopper cavity. By passing charged particles into the deflecting assembly during only about 10% of the chopper cycle it should be possible to obtain bursts with a duration of about $\frac{1}{30}$ nanoseconds. The deflection plates can be used with gas thyratrons or hard tubes. In the latter case higher repetition rates and rise times can be obtained.

In the deflector, assembly **14** of the deflection plate **52** is grounded and deflection plate **51** is held at a potential of approximately 10 kv. Similarly, the deflection plate **62** is grounded and deflection plate **61** is held at a positive potential of approximately 10 kv. The particle deflection in the region of the second pair of plates **61** and **62** due to the electric field between the plates is counterbalanced by the magnetic field supplied by the coils **67**. The positively charged deflection plates **51** and **61** are connected to the thyratrons **55** and **65** which may be independently triggered to provide pulse length control. During the initial portion of the pulse, deflection plates **51** and **61** are positively charged such that the diverging beam pulse passing between the first pair of plates **51** and **61** is radially deflected from the axis of the deflection assembly, passes through the field of the focusing lens **46** where some image rotation is produced, and is focused in the slot **49** at the collector **47** radially displaced from the axially located collimating aperture **48**. No deflection action is experienced by the converging beam in passing through the second pair of plates **61** and **62** because of the biased field condition.

When the first deflector plate **51** is rapidly discharged by triggering its driver thyratron **55**, the beam suddenly becomes symmetrically located about the center line of the deflection system causing the focal point to sweep along slot **49** in the collector **47** into the collimating aperture **48** and provide injection into the prebuncher cavity **71** and subsequently into the accelerating structure. After a suitable controllable time delay, deflector **61** is discharged by its thyratron **65** and the DC magnetic bias field remaining in the region between the second pair of plates causes the beam to be deflected away from the collimating aperture **48** and swept onto the collector surface **47**. One or more chopped and bunched particle bursts may be passed into the accelerating structure using this unique deflection assembly.

A number of advantages flow from this structure. The major advantage lies in the capability of continuous and smooth variations of pulse lengths from maximum cathode pulse lengths down to fractions of a nanosecond. Additionally, not only can very short pulses be produced but also they can be produced any time during the initial cathode pulse. For example, by selecting a portion at the middle of the pulse it is possible to avoid low current bursts such as occur during the rise and fall times of the pulse. This also permits selection of substantially constant energy particles for insertion into particle accelerators that can only accelerate particles over an extremely tight energy spread as required in sophisticated nuclear experiments.

The pulsing and accelerating structure in accordance with the present invention can produce either a high current or high energy particle pulse for performing a variety of experiments. In this regard with the three accelerating waveguides **17**, **18** and **19** fed with power from the dual output klystron in the manner shown in FIG. 1, a high energy and medium current output can be achieved such as, for example, an output of 25 mev. and 270 ma. when each output arm of the klystron is carrying 8 mw. By switching the RF power remaining at the output end of the first accelerating section **17** from the phase shifter **22** to a load **92** indicated in phantom in FIG. 1 and directing the second output from the dual output klystron via line **91** as shown in phantom in FIG. 1 to the second accelerating section **18** instead of the third accelerating section **19**, a high current medium energy particle output can be achieved at the output end of the second section **18**. This high current output can be, for example, on the order of 1 amp at 11 mev. or 2.5 amps at 4 mev. or other values depending upon the operating parameters. This accelerator construction permits the trapping and bunching fields which vary from cavity to cavity in the initial accelerating waveguide **17** to be utilized and maintained for both the high current and high energy operations while the phase shifter **22** between the first and second accelerating sections **17** and **18** provides a means of varying the beam energy and counteracting the small phase shifts due to heavy beam loading.

In order to utilize the high current particle pulse from the output of the second waveguide section **18**, the third waveguide section **19** must be decoupled from the particle beam so that the net transfer of energy from the beam to the RF structure is zero. One possible arrangement to avoid beam losses in the third accelerating waveguide section **19** is to displace the third accelerating section **19** from the axis of the remaining accelerating structure **17** and **18**. However this construction requires mechanical movement of accelerating guide **19** as well as the requisite opening of the high vacuum system.

As an aspect of the present invention provision is made for changing the operating temperature of the third accelerating waveguide **19** to phase slip the microwave circuit of that accelerating waveguide from the particle beam transmitted therethrough thereby permitting passage of the particle beam through accelerating waveguide **19** without energy loss due to induction of fields in the waveguide. Decoupling of this section is accomplished by adjusting the heater **20** to change the temperature of the cooling fluid and thereby the operating temperature of the waveguide. In this manner the phase relationship between the particle bunches and the traveling wave continuously varies in such a manner that the net transfer of energy can be controlled to produce a zero net transfer of energy from the particle pulses of the RF structure.

By way of example, by changing the normal operating temperature of an S-band frequency waveguide as described in the example above from, for example, 40° C. to approximately 75° C. the waveguide can be decoupled from the high current, medium energy particle pulse emanating from section **18** so that this particle pulse can be directed through waveguide **19** without substantial loss of beam energy.

While the invention has been described with respect to a three section linear accelerator it can be utilized with accelerators having a greater number of sections. Also the heater **20** is utilized to schematically illustrate a temperature control means. A cooling unit could be utilized.

While the invention has been described above with reference to positioning of the chopping cavity upstream of the prebunching cavity this construction requires proper phasing between the signals as applied to the separate cavities and control of the induced fields in the prebuncher activity due to the chopped beam passing therethrough. Referring now to FIG. 6, there is shown a structure wherein this beam-induced field is avoided. As shown, a pulse of charged particles is generated in the beam generating assembly **12** and passed through a chopping cavity **34** directly into the beam deflection and injection assembly **14** without clipping of the pulse on a collector. In the deflection assembly **14** the successive pairs of plates **51–52** and **61–62** are utilized to sweep the pulse of particles across the collector **47** downstream thereof for passage of the portion of the pulse through the collimating aperture **48**. In this arrangement the positions of the plates **61** and **62** are reversed so that instead of moving across the collimating aperture from one side of the other the pulse is moved into the aperture from one side an then moved back out of the aperture on the same side. The prebunching cavity **81** is positioned between the second pair of plates **61** and **62** and the collector **47**. This cavity **81** which is preferably a circular TM_{010} mode cavity is provided with an input disc wall **82** having an elongate slot **83** aligned with the deflection path of the charging particle pulse and an output disc wall **84** having a similarly oriented slot **85**.

In the operation of the device shown in FIG. 6 the chopper deflected pulse of particles introduced into the cavity **81** is swept across the collecter **47** by operation of the deflection plates in a manner similar to that described above with reference to FIGS. 1–5 to pass a portion of the pulse through the collimating aperture during each cycle of the chopper cavity. After passage of the particles through cavity **81** the pulse is bunched due to the influence of an RF signal coupled thereinto by a coupling member **86**. The end result is a beam path which positions the beam for passage through the collimating aperture **48** during a portion of the cathode pulse as shown in FIG. 8C. Only one collector is utilized and induced fields in the prebunching cavity due to only clipped portions of the beam passing therethrough are avoided.

Naturally many modifications can be made in the construction of the present invention without departing therefrom. For example, the counterbalancing magnetic field produced by the coils **67** can be omitted and both plates **61** and **62** maintained at the same positive potential until the end of the desired pulse length at which time one of the plates is discharged to ground. While the slot **49** in the collector **47** in the structure of FIGS. 1–5 is designed for sweeping the particle beam forwardly into the collimating aperture **48** and again forwardly out of the collimating aperture **48**, it is obvious that the potentials on the deflecting plates can be selected for deflecting the particle beam forward into the collimating aperture **48** and then rearwardly out of the collimating aperture **48**. Additionally, the chopping cavity can be placed downstream of the prebunching cavity; in this case velocity modualtion of the beam through the chopping cavity will result in an RF deflection pattern correspondingly modified, and this effect may be used to enhance the selection of varied electrons for a tighter phase spread of resultant prebunched beams.

While the chopping cavity having a transverse magnetic field arranged across its center path has been described primarily for passage of only a portion of the particle beam therethrough, an arrangement of a pair of such cavities would also provide an extremely accurate beam position signal. For example, when located on the beam center line of a linear accelerator two rectangular TE_{102} cavities connected together and oriented at right angles can be adjusted to indicate in which quadrant the beam charge "center of gravity" lies. Similarly such a device with each cavity energized at the fundamental RF frequency but 90° out of electrical phase can deflect a beam passing therethrough to produce a circular scan at the RF cyclic frequency. Such a device can act as a bunch length monitor as a bunched beam of the same frequency made to pass through this device will produce only an arc of a circle such that the arc length divided by the full circumference and multplied by 360° gives the actual bunch length.

Since many changes can be made in the above construction and many apparently widely different embodiments of the invention can be made without departing from the scope thereof it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. An accelerating structure including a plurality of accelerating waveguides, means for directing radio frequency energy into each of said waveguides and for decoupling said radio frequency energy from one of said waveguides, means for directing charged particles through said waveguides for interaction with radio frequency energy therein for acceleration of said particles to relativistic velocities, means for cooling each said waveguides, and means for heating said one waveguide to change the dimensions of said one waveguide and electrically decouple said one waveguide from the particles passing therethrough.

2. An accelerating structure for providing high current medium energy charged particle beams and medium current high energy charged particle means comprising:
- means for creating a beam of charged particles,
- a plurality of accelerating waveguide sections including at least first, second and third accelerating sections for interacting with said beam,
- input power means connetced to said first section,
- a first phase shifting means connected between said input power means and said second and third sections

for selectively directing power to said second section for high current medium energy beams and to said third section for medium current high energy beams,

a second phase shifting means connected to said first and second sections,

a load connected to said first section, and said first section including means for selectively directing power from said first section to said load for providing high current medium energy beams and to said second phase shifting means for providing medium high energy beams.

3. The accelerating structure of claim 2 including means for electrically decoupling at least one of said sections from the particle beam passing therethrough.

4. The accelerating structure of claim 3 wherein said decoupling means includes means for selectively changing the temperature of said one of said sections.

5. The accelerating structure of claim 4 wherein said temperature changing means comprises a heater.

6. The method of changing the mode of operation of an accelerator from a medium current high energy first mode to a high current medium energy second mode;

said accelerator comprising in said first mode means for creating a beam of charged particles; first, second and another accelerating waveguide sections for interacting with said beam; means coupling input power to the waveguide input of said first section and to the waveguide input of said other section; and coupling means between the waveguide output of said first section and the waveguide input of said second section;

said method of changing to said second mode comprising the steps of:

decoupling the waveguide output of said first section from the waveguide input of said second section;

decoupling said input power from the waveguide input of said other section and coupling said input power to the waveguide input of said second section;

and decoupling said other section from said beam.

7. The method of changing the mode of operation of an accelerator from a high current medium energy first mode to a medium current high energy second mode.

said accelerator comprising in said first mode means for creating a beam of charged particles, first and second accelerating waveguide sections for interacting with said beam, a phase shifter, input power means coupled to the waveguide input of said first section and to said phase shifter, and means coupling said phase shifter to the waveguide input of said second section,

said method of changing to said second mode comprising the steps of:

decoupling said phase shifter from said second section,

coupling the waveguide input of a third accelerating waveguide section to said phase shifter to interact with the beam from the second section,

and coupling a second phase shifter between the waveguide output of said first section and the waveguide input of said second section.

8. In a charged particle beam device having means for passing a beam of charged particles through a waveguide section in a manner which will cause energy loss from the beam to the waveguide section at a given temperature of the waveguide section, the method of decoupling said waveguide section from said beam by changing the temperature of the waveguide section to change the dimension of the waveguide section and phase slip said waveguide from said beam to cause substantially zero net transfer of energy from the beam to the waveguide section.

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JAMES W. LAWRENCE, *Primary Examiner.*

V. LAFRANCHI, *Assistant Examiner.*