

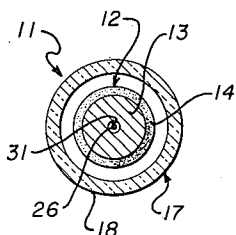
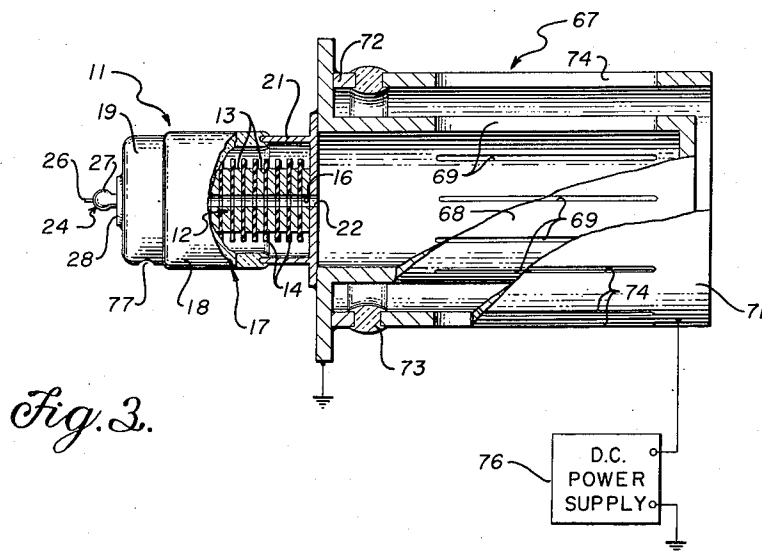
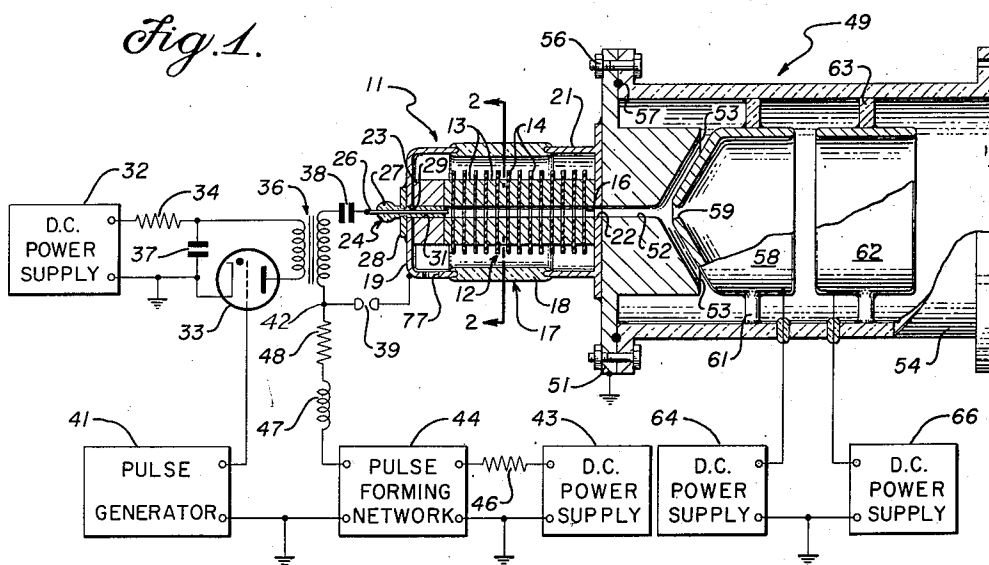
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ION SOURCE

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2,764,707

ION SOURCE

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The present invention pertains to ion sources in general and more particularly to an ion source for providing a high density ion beam.

Such ion beams are used in a variety of particle accelerators, i. e., linear accelerators, cyclotrons, bevatrons, Van de Graaff accelerators, and sundry other applications. One of the difficulties attending the successful operation of these machines has been the provision of a sufficient density of ion beam without coincident contamination with neutral gas molecules.

In the ion source of the present invention a novel plasma emitting element comprising a stack of interleaved metal annuli having a selected gas occluded therein and insulating material spacers simultaneously performs the function of the anode and cathode arc electrodes and of the external gas supply utilized in conventional ion sources. Such structure is highly advantageous in that the frequency and duration of plasma generation periods, i. e., simultaneous gas emission and ionization, can be very accurately controlled and regulated. In the operation of an ion source incorporating the novel plasma generating unit, an electrical impulse is impressed across the stack in such a manner as to confine arcing across the inner periphery of the insulating spacers, whereby the metal-occluded gas annuli release gas which is instantly ionized by the arc, thereby providing an electrically neutral ionized gas in the bore defined by the stacked annuli. Such an electrically neutral ionized gas is conventionally termed a plasma, i. e., a space charge neutralized ion gas. Provision is also made whereby the ions so produced may be accelerated by an electrode assembly which may be appropriately modified in design to provide the type of ion beam required in various devices.

The device of the present invention can be operated with discrete pulse duration as small as a fraction of a microsecond and will produce a high density accelerated ion beam containing a high percentage of monatomic ions with no associated gas production between pulses. Also, the magnitude of the ion beam produced by the ion source is determined by the impressed voltage and other characteristics of the electrical impulse used for establishing the electrical arc and thus can be selected.

It is therefore an object of the present invention to provide a new and improved ion source.

One object of the invention is to provide an ion source capable of producing a high density accelerated ion beam.

Another object of the invention is to provide an ion source that can be operated for selected pulse durations ranging upward from a fraction of a microsecond.

An additional object of the invention is to provide an ion source that does not have associated gas production between pulses, thereby providing a high ionization efficiency and greatly diminished contamination of the vacuum system.

A further object of the invention is to provide an ion source that will permit selection of beam magnitude.

A still further object of the invention is to provide an

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ion source that will produce an ion beam having a high proportion of monatomic ions.

An important object of the invention is to provide an apparatus utilizing a novel gas emitting element comprising interleaved metal-occluded gas annuli and insulating spacing material simultaneously serving the function of the arc electrodes and external gas source used in conventional ion sources.

The invention both as to its organization and method of operation, together with further objects and advantages thereof, will be best understood by reference to the following specification taken in conjunction with the accompanying drawing, of which:

Figure 1 is a longitudinal cross sectional view of a preferred embodiment of the invention incorporating an apertured electrode structure for axial extraction;

Figure 2 is a cross section taken along the plane 2—2 of Figure 1; and

Figure 3 is a cross sectional view of an electrode structure appropriately modified to provide radial extraction.

In brief, the ion source of the invention utilizes in combination in an evacuated system, an assembly of novel construction having spaced gas emitting surfaces encompassing a central bore from which a plasma may be emitted and accelerating electrode means adapted to assist in extracting and accelerating ions of the plasma from the bore. Especially adapted electrical circuitry is employed to initiate emission and simultaneous ionization of the gas causing the formation of a plasma in the bore and further to sustain and augment such plasma production for a discrete period of time, whereby energetic ions are cor-
relatively supplied by the ion source.

More particularly, referring to the accompanying drawing, such plasma generator assembly, indicated generally at 11, will essentially include a stack 12 of interleaved, especially prepared, gas saturated metallic annuli 13 and thin dielectric annuli 14 as shown in Figs. 1 and 2. Such metallic annuli 13 may be formed of one of the transition group metals such as titanium, tantalum, palladium, zirconium, and other metals which are characterized by their ability to occlude large amounts of certain gases, particularly the hydrogen isotopes. To saturate the metallic annuli 13 with the desired gas, e. g., H₂, D₂ or T₂, the metallic annuli are outgassed at several hundred degrees centigrade (red heat) in an evacuated system and then the gas to be occluded is admitted to contact the heated metal at atmospheric pressure. The metal is allowed to cool slowly for approximately one hour during which time the metal absorbs large amounts of the gas. The gas occluded or absorbed by the cooled metal will be retained even in the very highest vacuums until such time as an electrical arc is formed thereto as described herein-
after. Titanium is a metal preferred for this purpose since it is capable of retaining very large amounts of the gas and possesses other requisite properties to a highly satisfactory degree.

The dielectric annuli 14 are constructed of insulating material such as mica and are considerably thinner than the metallic annuli 13. The interior diameters of both the annuli 13 and 14 are made approximately equivalent thereby forming a centrally located bore 16 of substantially constant diameter through the stack 11. However, the outer diameter of the dielectric annuli 14 is made larger than that of the metallic annuli 13 whereby the overlapping edge aids in suppressing sparking in the outer surface area of the stack 11. The threshold voltage for breakdown across the bore surfaces of the dielectric annuli is dependent on their thickness, which thickness should be uniform and of sufficient magnitude to assure uniformly distributed arcing and to prevent puncture from sparking therethrough, thus insuring sparking across the aforesaid bore surfaces. With other forms

of construction, the insulating means may comprise other dielectric material or merely an insulating space provided provision is made to assure that plasma generation takes place only in said bore.

As usually constructed, the plasma generating assembly 11 will include an envelope 17 which may take the form of a tubular insulator section 18 constructed of material such as glass which is fused to an electrical conducting closure cap 19 at the rear extremity thereof. Similarly the forward extremity of the tubular section 18 is fused to a grounded electrical conducting closure cap 21 outwardly flanged at the distal extremity for attachment of an electrode ejector or extractor assembly more fully described hereinafter.

The stack 12 is terminated at both extremities with one metallic annulus 13 and is disposed within the envelope 17 coaxially therewith in such a manner that the bore 16 is in alignment with an exit aperture 22 of the same diameter centrally located in the closure cap 21. To provide a means to hold the stack 12 securely together and flush against the forward closure cap 21, a cylindrical spacer 23 formed of electrical conducting material is disposed between the rear extremity of the stack 12 and the closure cap 19.

The hereinbefore-mentioned means employed to initiate emission and simultaneous ionization of the gas occluded in the bore surfaces of the metallic annuli 13, whereby a plasma is formed, may comprise means adapted to provide a spark thereto, such as by a triggering electrode assembly 24 supported by the cap 19 and energized by an electrical circuit means as will be more fully disclosed hereinafter. While it is convenient to employ such an electrode to initiate operation of the source any means which may be adapted to cause the initial discharge and subsequent formation of a conduction path therein may likewise be employed. Such equivalent means may include an electron gun, ionizing radiation, ultraviolet light sources, and means adapted to apply a high localized temperature. The triggering electrode assembly 24 includes a slender cylindrical electrode 26 enclosed in a tubular fused vitreous insulator 27 and a metallic ring 28 disposed radially about the shank of the insulator 27 and secured by fusing. The shank portion of the electrode assembly 24 is disposed in an aperture 29 centrally located in the closure cap 19 and which extends as a bore 31 axially through the spacer 23 in alignment with the bore 16 in said stack 12, in such a manner that the ring 28 fits flush against, and may be attached as by brazing or welding to the exterior surface of the cap 19 forming a hermetic seal therebetween. To provide the spark which is employed to initiate plasma generation, the forward extremity of the electrode 26 is extended a short distance outward from the insulator 27, disposed in bore 31, and is terminated coaxially with reference to the rearmost metallic annulus 13.

For energizing the triggering electrode 26 to initiate sparking between the bore surfaces of the metallic annuli 13, there may be employed a pulse generating circuit including a D. C. power supply 32 having the grounded negative terminal connected to the cathode of a negatively biased thyatron 33, with the positive terminal connected through a limiting resistor 34 to one terminal of the primary of a step-up pulse transformer 36, and the anode of the thyatron 33 coupled to the other terminal of the primary of the step-up pulse transformer 36, whereby a sharply rising electrical current can be applied from said supply 32 to the primary winding of transformer 36. To enhance the discharge capacity of the supply, energy storage means, e. g., a storage capacitor 37 may be shunted across the terminals of the power supply 32, necessarily on the transformer side of the resistor 34 and the cathode side of the thyatron 33. In order to apply the exciting current, one terminal of the secondary of the transformer 36 is connected to the electrode 26 through a blocking capacitor 38, and the other terminal of the transformer

secondary is connected to the closure cap 19 through a ball gap 39. Actuation of the pulse generator may be accomplished by means of a pulse generator 41 coupled to the grid of the thyatron 33 to provide a normal negative bias followed by a positive pulse signal. The pulse generator is of any conventional design and may be adapted for application of an external triggering signal which is supplied by control apparatus of the device with which the ion source is employed. In this manner the ion source may be actuated very precisely as required in the operation of the associated apparatus.

The hereinbefore-mentioned electrical means employed to sustain arcing across the bore surfaces of the metallic annuli 13 for extended periods of time may comprise a circuit adapted to apply a sustained high current thereacross. It is convenient and very effective to provide a pulse line voltage to a juncture 42 between the secondary of the step-up pulse transformer 36 and the ball gap 39. Such a voltage may be provided by a circuit including a D. C. power supply 43 having one terminal connected to the input terminal of a conventionally designed pulse forming network 44 as through a current limiting resistor 46 with the other terminal of the supply 43 being connected directly to the network 44. The output terminal of the pulse forming network 44 may then be coupled to said juncture 42 through a series inductance 47 and a series network terminating resistor 48 with the electrical return path being formed through a common ground circuit through the cap 21 as described below.

In operating the plasma generator assembly 11, a positive pulse is applied from the pulse generator 41 to the grid of the thyatron 33, thereby permitting current from the storage capacitor 37, previously charged by the power supply 32, to discharge through the primary of the pulse transformer 36. The secondary of the transformer 36 will then deliver a large pulsed voltage to the electrode 26 through the blocking capacitor 38, which will cause a spark to occur between the forward extremity of the electrode 26 and the metallic annulus 13 nearest thereto. The current will simultaneously return to the secondary of the transformer 36 through the spacer 23, the closure cap 19, and across the ball gap 39 causing initiation of an arc therein. It will be noted here that the heat imparted to the bore surface of the aforesaid gas occluded metallic annulus by the spark will cause gas emission and simultaneous ionization so as to initiate plasma production within the bore 16 and, further, to insure confinement of arcing to only the bore surfaces by providing a preferential conduction path for the sustaining pulse line current whereby external sparking, i. e., sparking across the external surfaces of the stack 12, is prevented.

To sustain the plasma production initiated by the triggering device, the power supply 43 previously charges the pulse forming network 44 and the static potential of the supply 43 is chosen at a level insufficient to arc across the ball gap 39 and being a D. C. voltage will not traverse the blocking capacitor 38, thus the pulse line current will remain quiescent until the arc is provided across the ball gap 39 as noted above. At the instant the initiating spark crosses the ball gap 39, a sustained pulse of current will be discharged from the pulse forming network 44 through the inductance 47, the terminating resistor 48, across the ball gap 39 to the closure cap 19, along the metallic spacer 23 and as a series of arcs across the insulated gaps between the bore surfaces of the metallic annuli 13 to the ground cap 21.

It will be noted that the inductance 47 is provided to prevent premature extinction of the sparking before the pulse forming network 44 is completely discharged. Should the current tend to decrease, the back E. M. F. builds up in the inductance and tends to maintain the current, thereby providing a steady pulse height. At this point it may be noted that the ball gap 39 is not necessary when the insulating annuli 14 have a high leakage resistance for the pulse line voltage since the gaps be-

tween the annuli may then serve a similar function. In the instance where no ball gap is necessary, the pulse line voltage provided by the pulse forming network 44 will not discharge across the stack 12 until ionization is initiated by the triggering means previously described providing the indicated conduction path therethrough.

It will be noted here that gas emission and simultaneous ionization is confined exclusively to the duration of the electrical arc as determined by the electrical characteristics of the circuit applying the sustaining current and will cease upon discontinuance thereof. Thus the plasma may be repetitiously produced at frequencies controlled by the pulse generator and for pulse durations determined by the characteristics of the pulse forming network 44 which determines the time interval required to completely discharge the pulse line voltage across the stack 12. Therefore the frequency and duration of the plasma production can be readily controlled by proper adjustment of the pulse generator 41 and appropriate selection of the pulse forming network 44. In addition, the rate of plasma production is dependent on the pulse line voltage and therefore may be easily controlled by adjustment of such voltage. Exceedingly high ionization efficiency is obtained since only the bore surfaces of the annuli directly affected by the electrical arc will emit gas, and essentially all of the gas emitted is instantly ionized by the same arc that caused the gas to be emitted. Thus very little neutral gas is produced thereby introducing little contamination into the system.

The plasma produced in the aforementioned manner in the bore 16 will diffuse or otherwise progress out of the exit orifice 22 where the ions of the plasma may be accelerated and focused by various electrode ejector means described in detail hereinafter or otherwise utilized as such in apparatus with which the ion source is employed. Either axial or radial ion beams may be obtained as described hereinafter. Such accelerating electrode means for axially extracting the ions of the plasma produced by the plasma generating assembly 11 may comprise an axial ejector electrode assembly 49 extending forwardly from the forward closure cap 21 of assembly 11 as shown in Fig. 1. The electrode assembly 49 includes a cylindrical grounded electrode 51 outwardly flanged at the rearmost extremity and having a centrally located longitudinal cylindrical bore 52 terminating in a flaring conical face 53 at the forward extremity thereof. The bore 52 is aligned with the exit aperture 22 of the plasma generating assembly 11 with the cap 21 secured to the grounded electrode 51 in a hermetic fashion as by welding the outward flange of the closure cap 21 to the flanged extremity face of electrode 51. Electrode 51 may be considered as an extension of the forward cap 21 of the plasma generating assembly whereby some plasma collimation is obtained and proper accelerating electrode spacing is obtained. Assembly 49 also includes a cylindrical vacuum housing 54 flanged at the forward extremity for attachment to the evacuated system of a device utilizing the ion source, while the rearward extremity may be flanged for attachment to the forward face of the flanged portion of the ground electrode in coaxial alignment as by fasteners 56. An annular sealing element 57 disposed between the flanges of ground electrode 51 and the housing 54 provides an airtight seal therebetween.

Extraction of ions from the orifice 22 through the bore 52 of the electrode 51 is obtained with an extraction electrode 58 disposed in the housing 54 outwardly from the face 53. Such electrode may be formed of a uniform cylindrical tubular portion in the forward region and tapered cylindrically in the rearward region so as to terminate in an aperture 59 at the apex thereof. Such electrode 58 is preferably disposed coaxially within the housing 54 such that the outer face of the tapered extremity is spaced somewhat from the conical bore 53, whereby the aperture 59 is in alignment with the bore 52. Such alignment may be obtained by means of a plurality

of insulating supports 61 secured to the exterior surface of the electrode 58 and to the interior surface of the housing 54. An accelerating cylindrically tubular electrode 62 may also be supported in the housing 54 a short distance forward and coaxial with the electrode 58 providing a gap therebetween, utilizing a plurality of insulating supports 63. In the event that the housing is formed of an insulating material, e. g., glass or ceramic, the said supports could be of metal.

Extraction potential may be applied to electrode 58 as by a D. C. power supply 64 having the positive terminal grounded and the negative terminal connected to the electrode 58, thereby providing a continuous negative potential thereto which is effective in extracting and axially accelerating positive ions emerging from the bore 52. A second D. C. power supply 66 having the positive terminal grounded and the negative terminal connected to the second accelerating electrode 62, provides a selected large continuous negative potential thereto for the purpose of accelerating ions extracted by electrode 58. In operation the ground electrode 51, the electrode 58 which assists in determining the magnitude of the extracted ion beam, and the second accelerating electrode 62 having strong focusing properties, provide an electrical field configuration that will extract, accelerate, and axially focus the ions of the plasma as it is repetitiously produced by the plasma generating assembly 11, thereby providing a pulsed axial ion beam. This type of extraction ideally adapts the ion source of the invention for utilization in devices such as linear accelerators, Van de Graaff accelerators, and the like wherein a focused linear ion beam can be used to advantage.

An accelerating electrode means for radially extracting the ions of the plasma produced by the plasma generating assembly 11 may comprise a radial ejector electrode assembly 67 as shown in Fig. 3. The electrode assembly 67 includes a cylindrical cup ground electrode 68 closed at the forward extremity and having an outwardly flanged rear extremity adaptable for attachment in axial alignment to the plasma generating assembly 11 in a hermetic fashion as by welding the flanged closure cap 21 thereto. Thus the plasma produced by the plasma generating assembly 11, will diffuse or otherwise progress from bore aperture 22 into the chamber of the ground electrode 68. The ground electrode 68 is provided with either radial or longitudinal peripheral slots 69 providing exit passageways for the ions of the plasma when accelerated by a cylindrical extracting and accelerating electrode 71 disposed a short distance radially outward therefrom. For convenience the accelerating electrode 71 is secured to a metallic ring 72 attached as by welding to the forward face of the flanged extremity of the ground electrode 68, by means of an annular insulating, e. g., vitreous element 73 disposed therebetween. To permit radial emergence of the extracted ions, the electrode 71 has formed therein peripheral slots 74 aligned with the slots 69.

Extraction and acceleration potential is applied to the electrode 71 by a D. C. power supply 76 having the positive terminal grounded and the negative terminal connected to the electrode 71. Generally speaking, the ion source, as adapted for radial extraction, will be employed in a device which supplies a magnetic field (H), e. g., axially symmetric magnetic field to the ion source. With this type of field present, the plasma emerging from the bore aperture 22, is confined to the axial region of the chamber of electrode 68. In apparatus not adapted to supply such a field, an electrically energized coaxial solenoid (not shown) may be substituted. Thus in operation a high negative voltage is supplied to the accelerating electrode 71 and positive ions of the plasma, repetitiously produced by the plasma generating assembly 11, will be extracted from the chamber of electrode 68 and ejected radially outward while excess electrons present will flow to the ground electrode 68. The ion source adapted for

this type of extraction is readily disposed on the magnetic field axis of devices such as the cyclotron.

It is not intended to limit the invention to the particular electrode ejector assemblies 49 and 67 for axial and radial ion extraction respectively, since various other ejector configurations may be employed to obtain the type of ion beam desired.

For proper operation of the ion source of the invention it is necessary that at least the electrode ejector assembly be in communication with an evacuated system of the device utilizing the ion source to insure evacuation of the ion source chambers. Also, the chamber between the stack 12 and the envelope 17 should be continuously outgassed as by a vacuum pump (not shown) communicating therewith as through an aperture 77 (see Fig. 1) provided in the closure cap 19 in the event that free passage to the bore is not present. Briefly in operating the ion source, each time the ion source is pulsed the aforementioned triggering device initiates plasma production in the bore 16, thereby providing a conduction path which enables the pulse line voltage to discharge there-through and sustain plasma production through the bore 16 for the duration of the discharge. The plasma simultaneously emerges from the bore orifice 22 whenceforth the ions of the plasma are extracted, accelerated, and ejected by a continuously energized electrode ejector assembly such as the axial electrode ejector assembly 49 whereby an accelerated and focused pulsed axial ion beam is produced, or as by the radial ejector assembly 67 whereby a radial pulsed array of ion beams is produced. For example, a pulsed axial ion beam having a density of from 2 to 3 amp./sq. inch was produced by the ion source configuration utilizing the axial accelerating electrode ejector assembly 47 with the circuitry shown in Fig. 1 wherein conventional components were utilized to supply 20 kv. to the electrode 26, a 10 kv. pulse line voltage at the juncture 42, and negative potentials of 10 kv. and 60 kv., respectively, to the accelerating electrodes 58 and 62.

While the invention has been described with reference to preferred embodiments, it will be apparent to those skilled in the art that numerous variations and modifications may be made within the spirit and scope of the invention and thus it is not intended to limit the invention except as defined in the following claims.

What is claimed is:

1. A plasma generating unit comprising an assembly of interleaved dielectric and metallic annuli defining a bore, said metallic annuli being treated to provide hydrogen isotopes occluded therein.

2. A plasma generating unit comprising an assembly including dielectric annuli interleaved with metallic annuli having a hydrogen isotope occluded therein, thereby defining a bore, and means terminating adjacent to and adapted to initiate an electrical spark to the bore surface of at least one of said metallic annuli.

3. A plasma generating unit comprising an assembly including dielectric annuli interleaved with metallic annuli having a gaseous material occluded therein thereby defining a bore, and means adapted to cause emission and initiating ionization of the gaseous material occluded in said metallic annuli.

4. A plasma generating unit comprising an assembly including dielectric annuli interleaved with metallic annuli having a gaseous material occluded therein thereby defining a bore, means adapted to cause emission and initiating ionization of the gaseous material occluded in said metallic annuli, and means adapted to apply an electrical potential across said metallic annuli so as to discharge therebetween on application of said initiating ionization thereby sustaining and augmenting plasma production in said bore.

5. A plasma generating unit comprising an assembly including dielectric annuli interleaved with metallic annuli having a hydrogen isotope occluded therein there-

by defining a bore, a housing for said assembly including an insulating central portion and terminal cap portions bearing longitudinally on said assembly and adapted for the application of an electrical potential thereacross, and electrode means terminating adjacent to and adapted to apply an initiating electrical spark to the bore surface of at least one of said metallic annuli.

6. An ion source comprising in combination an electrode having a central bore at least partially lined with a metal-occluded gas surface, electrical means for producing an electrical spark to said surface causing gas emission and simultaneous ionization whereby a plasma is formed, and accelerating electrode means adapted to extract and accelerate the ions of said plasma yielding an ion beam.

7. An ion source comprising in combination an evacuated envelope having an exit orifice, an electrode having a central bore at least partially lined with a metal-occluded gas surface and in communication with said exit orifice, electrical means for producing an electrical spark to said surface causing gas emission and simultaneous ionization whereby a plasma is formed in said bore, and accelerating electrode means arranged to extract and accelerate the ions of said plasma progressing through said orifice.

8. An ion source comprising in combination an evacuated envelope having an exit orifice, an electrode having a central bore at least partially lined with a metal-occluded gas surface and disposed within said envelope whereby said bore communicates with said exit orifice, first electrical means for producing an electrical spark to at least a part of said surface causing gas emission and simultaneous ionization whereby a plasma is formed in said bore, a second electrical discharge means actuated subsequent to said first means for applying an arc to said surface to sustain and augment said plasma production in said bore, and accelerating electrode means adapted to extract and accelerate the ions of said plasma from said orifice.

9. An ion source comprising in combination an evacuated envelope having an exit orifice, an electrode having a central bore encompassed by alternating dielectric and metal-occluded gas surfaces and disposed within said envelope with said bore communicating with said exit orifice, electrical means for producing an electrical spark to said metal bore surfaces causing gas emission and simultaneous ionization whereby a plasma is formed in said bore, and accelerating electrode means adapted to extract and accelerate the ions of said plasma through said orifice.

10. An ion source comprising in combination an evacuated envelope having an exit orifice, an electrode having a central bore encompassed by alternating dielectric and metal-occluded gas surfaces and disposed within said envelope whereby said bore communicates with said exit orifice, first electrical means for producing a spark to at least one of said metal bore surfaces causing gas emission and simultaneous ionization therein, second electrical means which is actuated to produce sustained arcing to said metal surfaces so as to sustain and augment said plasma production, and accelerating electrode means adapted to extract and accelerate the ions of said plasma through said orifice.

11. An ion source comprising in combination an evacuated envelope having an exit orifice, an electrode having a central bore encompassed by alternating dielectric and metallic surfaces having a gaseous material occluded therein, said electrode being disposed within said envelope whereby said bore communicates with said exit orifice, first electrical means for producing a spark to at least one of said metallic bore surfaces causing gas emission and simultaneous ionization whereby a plasma is formed in said bore, second electrical means providing electrical arcs to said metallic bore surfaces thereby sustaining and augmenting said plasma production

through said bore, and electrode means adapted to extract and accelerate the ions of said plasma arranged outwardly of said exit orifice.

12. An ion source comprising in combination an evacuated envelope having an exit orifice, an electrode having a central bore encompassed by alternating dielectric and metallic surfaces having a gaseous material occluded therein, said electrode being disposed within said envelope whereby said bore communicates with said exit orifice, electrical discharge triggering means for applying a spark to at least one of said metallic bore surfaces causing gas emission and simultaneous ionization whereby a plasma is formed and an electrical conduction path is provided in said bore, electrical pulse line means adapted to apply a potential across said bore surfaces whereby a sustained discharge occurs along said conduction path when said triggering means is actuated thereby sustaining and augmenting said plasma production through said bore, and accelerating electrode means arranged in communication with said exit orifice and adapted to extract and accelerate the ions of said plasma through said orifice.

13. An ion source comprising in combination an evacuated envelope having an exit orifice, a plasma generating electrode having a central bore encompassed by alternating dielectric and metallic surfaces having a gaseous material occluded therein, said electrode being disposed with said bore in axial alignment with said exit orifice, a triggering electrode terminating adjacent one of said metallic bore surfaces, a first electrical circuit energizing said triggering electrode providing a spark to said terminating metallic bore surface causing gas emission and simultaneous ionization whereby a plasma is formed and an electrical conduction path is provided in said bore, a second electrical circuit adapted to apply a potential which discharges across said bore surfaces when said conduction path is provided, thereby sustaining and augmenting said plasma production in said bore, and accelerating electrode means arranged outwardly of said exit orifice and adapted to extract and accelerate the ions of said plasma therethrough.

14. An ion source as described in claim 13 wherein said plasma generating electrode comprises a stack of interleaved dielectric and metallic annuli having gas occluded therein thereby providing said alternating dielectric and metal-occluded gas surfaces.

15. An ion source as described in claim 13 wherein said first electrical circuit comprises a pulse generating means adapted to provide a high potential to said triggering electrode.

16. An ion source as described in claim 13 wherein said second electrical circuit comprises a pulse forming network.

17. An ion source comprising in combination an evacuated envelope having an exit orifice, a plasma generating assembly including a stack of interleaved dielectric and metallic annuli having a gas occluded therein and defining a central bore therein, said element being disposed within said envelope with said bore axially aligned with said exit orifice, a triggering electrode terminating proximally to the bore surface of a terminating metallic annulus, pulse generating means adapted to provide a high potential to said electrode providing a spark to the bore surface of said terminating metallic annulus causing gas emission and simultaneous ionization whereby plasma production is initiated and an electrical conduction path is provided in said bore, a pulse forming network adapted to discharge across said bore surfaces when said conduction path is provided thereby sustaining and augmenting said plasma production through said bore, and accelerating electrode means arranged exteriorly of said exit orifice and adapted to extract and accelerate the ions of said plasma.

18. A pulsed ion source comprising in combination an evacuated envelope having an exit orifice, a plasma generating assembly including a plurality of metallic annuli hav-

ing a gaseous material occluded therein interleaved with a plurality of thin dielectric annuli having interior diameters equivalent to that of said metallic annuli and exterior diameters greater than that of said metallic annuli to aid in suppressing sparking thereacross forming a stack having a central bore therein and terminating at both extremities with one of said metallic annuli, said element being disposed with said bore being axially aligned with said exit orifice, a triggering electrode terminating proximally the bore surface of one of said terminating metallic annuli, pulse generating means adapted to repetitiously apply a high potential to said electrode providing a spark to the bore surface of said proximal metallic annulus causing gas emission and simultaneous ionization whereby plasma production is initiated and an electrical conduction path is provided in said bore, a pulse forming network adapted to discharge across said bore surfaces when said conduction path is provided thereby sustaining and augmenting said plasma production through said bore for a discrete period of time, and an accelerating electrode means arranged exteriorly of said exit orifice and adapted to extract and accelerate the ions of said plasma therethrough thereby providing a pulsed ion beam.

19. A pulsed ion source as described in claim 18 wherein said accelerating electrode means includes at least one annular electrode disposed outwardly and in axial alignment with said exit orifice and adapted for the application of an accelerating potential relative to said plasma generating assembly whereby the ions of said plasma are axially extracted and accelerated.

20. A pulsed ion source as described in claim 18 wherein said accelerating electrode means includes at least one electrode disposed radially outward from said exit orifice and adapted for the application of an accelerating potential relative to said plasma generating assembly whereby the ions of said plasma are extracted radially and accelerated.

21. A pulsed ion source comprising in combination an evacuated cylindrical envelope formed of an insulating cylindrical center section and with first and second conductor end cap closure elements, said second closure element being grounded and having an axial exit orifice, a plasma generating assembly including a plurality of metallic annuli having a gaseous material occluded therein interleaved with a plurality of thin dielectric annuli having interior diameters equivalent to that of said metallic annuli and exterior diameters greater than said metallic annuli to form a stack having a central bore therein and terminated with metallic annuli, said assembly being disposed within said envelope whereby said bore communicates with said exit orifice, an insulated triggering electrode transpiercing said first closure element and terminating proximally the bore surface of one of said metallic annuli, pulse generating means adapted to apply a high potential to said electrode providing an electrical spark to the bore surface of said proximal annulus whereby plasma production is initiated providing an electrical conduction path through said bore, a pulse forming network adapted to discharge a sustained current causing arcing across adjacent metallic annuli bore surfaces when said conduction path is provided thereby sustaining and augmenting said plasma production through said bore for a discrete period of time, a grounded cylindrical electrode hermetically secured to said second closure element and having a central bore axially aligned with said exit orifice and terminating outwardly in a conically divergent face serving to extend said bore, a first cylindrical tubular accelerating electrode having a diverging frusto conical portion disposed adjacent said diverging conical face and a cylindrical portion extending coaxially outward therefrom, and a second cylindrical tubular accelerating electrode disposed coaxially outward from said first accelerating electrode.

22. A pulsed ion source comprising in combination an evacuated cylindrical envelope formed of an insulating

cylindrical center section and with first and second conductor end cap closure elements, said second closure element being grounded and having an axial exit orifice, a plasma generating assembly including a plurality of metallic annuli having a gaseous material occluded therein interleaved with a plurality of thin dielectric annuli having interior diameters equivalent to that of said metallic annuli and exterior diameters greater than said metallic annuli to form a stack having a central bore therein and terminated with metallic annuli, said assembly being disposed within said envelope whereby said bore communicates with said exit orifice, an external vacuum pumping means arranged to outgas the intervening region between said assembly and said envelope, an insulated triggering electrode transpiercing said first closure element and terminating proximal the bore surface of one of said metallic annuli, pulse generating means adapted to apply a high potential to said electrode providing an electrical spark to the bore surface of said proximal metallic annulus whereby plasma production is initiated providing an electrical conduction path through said bore, a pulse forming network adapted to discharge a sustained current causing arcing across adjacent metallic annuli bore surfaces when said conduction path is provided thereby sustaining and augmenting said plasma production through said bore for a discrete period of time, a grounded cylindrical electrode hermetically secured to said second closure element and having a central bore axially aligned with said exit orifice and terminating outwardly in a conically diverging face serving to extend said bore, an evacuated cylindrical housing disposed coaxially outward and hermetically secured to said grounded electrode, a first cylindrical tubular accelerating electrode supported in insulated relationship within said housing and having a diverging frusto conical portion disposed adjacent said diverging conical face and a cylindrical portion extending coaxially outward therefrom, and a second cylindrical tubular accelerating electrode disposed in insulated relationship within said housing and coaxially outward from said first accelerating electrode.

23. A pulsed ion source as described in claim 22 wherein said cylindrical housing is adapted for attachment to the vacuum system of an apparatus utilizing said ion source.

24. A pulsed ion source comprising in combination an evacuated cylindrical envelope formed of an insulating cylindrical center section and with first and second conductor end cap closure elements, said second closure element being grounded and having an axial exit orifice, a plasma generating assembly including a plurality of metallic annuli having a gaseous material occluded therein interleaved with a plurality of thin dielectric annuli having interior diameters equivalent to that of said metallic annuli and exterior diameters greater than said metallic annuli to form a stack having a central bore therein and terminated with metallic annuli, said assembly being disposed within said envelope whereby said bore communicates with said exit orifice, an external vacuum pumping means arranged to outgas the intervening region between said assembly and said envelope, an insulated triggering electrode transpiercing said first closure element and terminating proximal the bore surface of one of said metallic annuli, pulse generating means adapted to apply a high potential to said electrode providing an electrical spark to the bore surface of said proximal metallic annulus whereby plasma production is initiated providing an electrical conduction path through said bore, a pulse forming network adapted to discharge a sustained current causing arcing across adjacent metallic annuli bore surfaces when said conduction path is provided thereby sustaining and augmenting said plasma production through said bore for a discrete period of time, a grounded cylindrical electrode hermetically secured to said second closure element and having a central bore axially aligned with said exit orifice and terminating outwardly in a

conically diverging face serving to extend said bore, an evacuated cylindrical housing disposed coaxially outward and hermetically secured to said grounded electrode, a first cylindrical tubular accelerating electrode supported in insulated relationship within said housing having a diverging frusto conical portion disposed adjacent said diverging conical face and a cylindrical portion extending coaxially outward therefrom, a second cylindrical tubular accelerating electrode disposed in insulated relationship within said housing and coaxially outward from said first accelerating electrode, a first D. C. power supply continuously supplying a negative potential to said first accelerating electrode whereby said first electrode will extract and accelerate the ions of said plasma from said bore, and a second D. C. power supply continuously supplying a high negative potential to said second accelerating electrode whereby said second electrode will further accelerate the ions of said plasma and axially focus ions thereby providing a dense pulsed accelerated axial ion beam.

25. A pulsed ion source comprising in combination an evacuated cylindrical envelope formed of an insulating cylindrical center section and with first and second conductor end cap closure elements, said second closure element being grounded and having an axial exit orifice, a plasma generating assembly including a plurality of metallic annuli having a gaseous material occluded therein interleaved with a plurality of thin dielectric annuli having interior diameters equivalent to that of said metallic annuli and outer diameters greater than said metallic annuli to form a stack having a central bore therein and terminating with metallic annuli, said stack being disposed within said envelope whereby said bore communicates with said exit orifice, an insulated triggering electrode transpiercing said first closure element and terminating proximal the bore surface of one of said metallic annuli, pulse generating means adapted to apply a high potential to said electrode providing an electrical spark to the bore surface of said proximal metallic annulus whereby plasma production is initiated instituting an electrical conduction path through said bore, a pulse forming network adapted to discharge a sustained current causing arcing across adjacent metallic annuli bore surfaces when said conduction path is provided thereby sustaining and augmenting said plasma production through said bore for a discrete period of time, a grounded slotted hollow cylindrical electrode disposed outwardly from and hermetically secured to said second closure element whereby the chamber of said grounded electrode communicates with said exit orifice allowing said plasma to enter therein, and a slotted hollow cylindrical accelerating electrode disposed radially outward from said ground electrode.

26. A pulsed ion source comprising in combination an evacuated cylindrical envelope formed of an insulating cylindrical center section and with first and second conductor end cap closure elements, said second closure element being grounded and having an axial exit orifice, a plasma generating assembly including a plurality of metallic annuli having a gaseous material occluded therein interleaved with a plurality of thin dielectric annuli having interior diameters equivalent to that of said metallic annuli and diameters greater than said metallic annuli to form a stack having a central bore therein and terminating with metallic annuli, said stack being disposed within said envelope whereby said bore communicates with said exit orifice, an external vacuum pumping means arranged to outgas the intervening region between said assembly and said envelope, an insulated triggering electrode transpiercing said first closure element and terminating proximal the bore surface of one of said metallic annuli, pulse generating means adapted to apply a high potential to said electrode providing an electrical spark to the bore surface of said proximal metallic annulus whereby plasma production is initiated instituting an electrical conduction path through said bore, a pulse forming network adapted

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to discharge a sustained current causing arcing across adjacent metallic annuli bore surfaces when said conduction path is provided thereby sustaining and augmenting said plasma production through said bore for a discrete period of time, a grounded slotted hollow cylindrical electrode 5 disposed outwardly from and hermetically secured to said second closure element whereby the chamber of said grounded electrode communicates with said exit orifice allowing said plasma to enter therein, a slotted hollow

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cylindrical accelerating electrode disposed radially outward from said slotted ground electrode, and a D. C. power supplying a negative potential to said accelerating electrode whereby the ions of said plasma are radially extracted and accelerated through slots of said electrodes thereby providing a radial pulsed array of accelerated ions.

No references cited.