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ION GUN IMPROVEMENTS FOR OPERATION IN THE MICRON PRESSURE RANGE AND UTILIZING A DIFFUSE DISCHARGE

Filed Oct. 11, 1966 Sheet 1 of 4

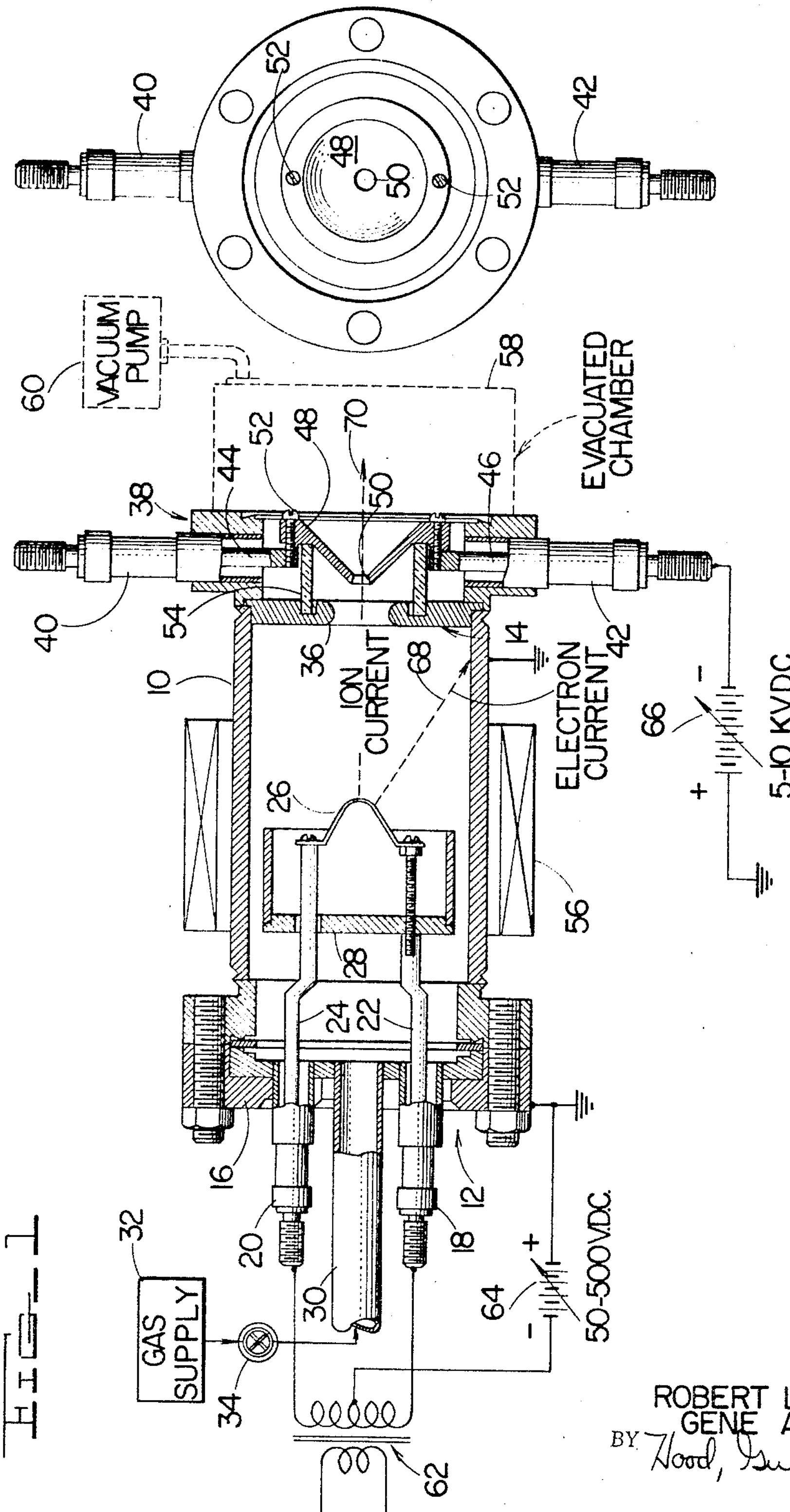

FIG. 2

FIG. 1

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FIG. 3

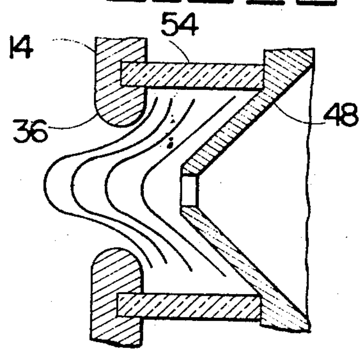
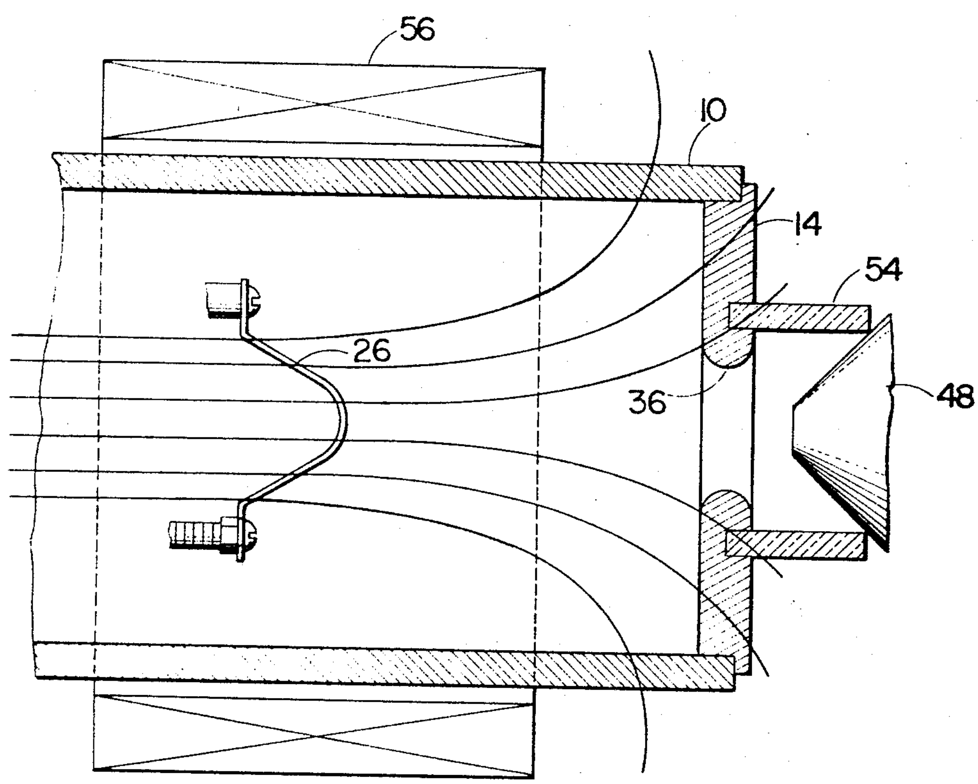


FIG. 4



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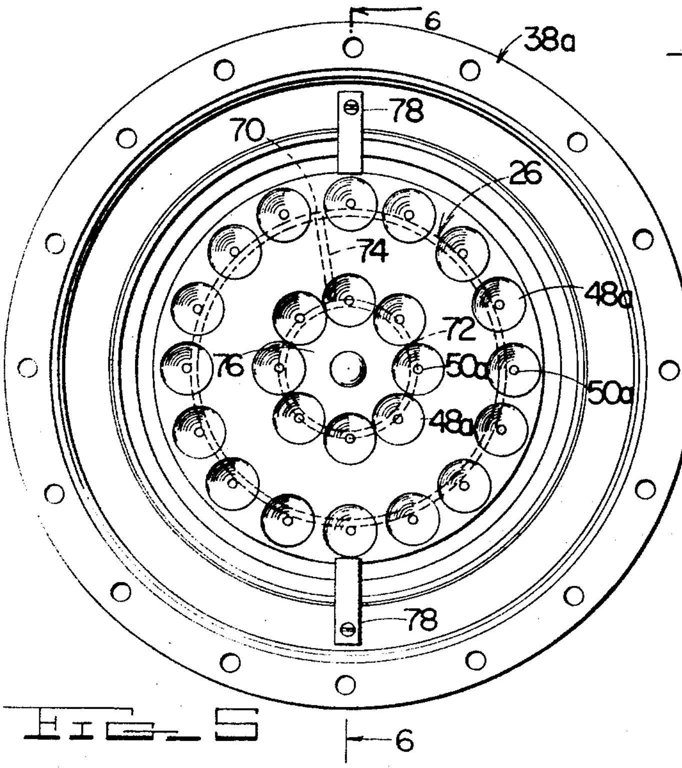

FIG. 5

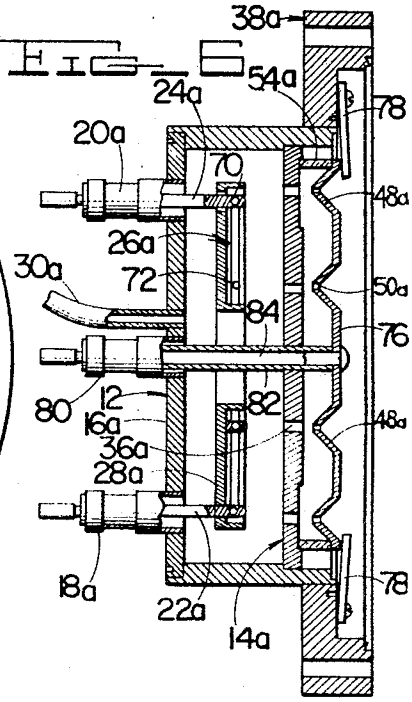

FIG. 6

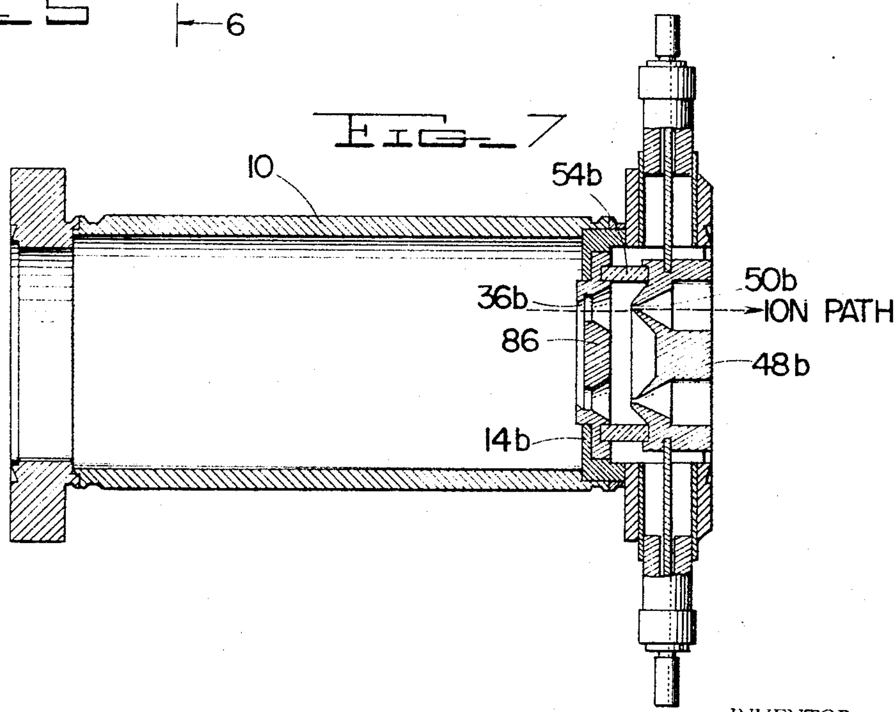

FIG. 7

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FIG. 8

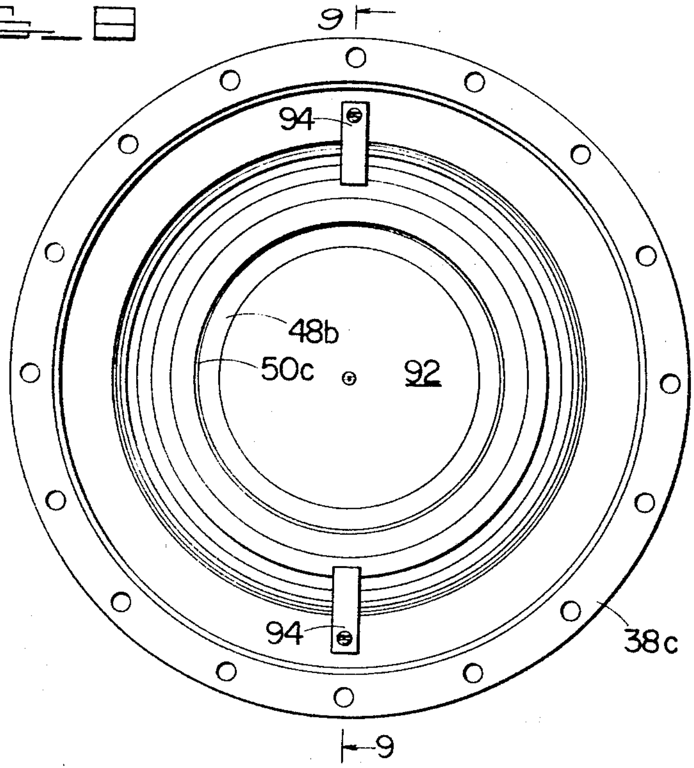
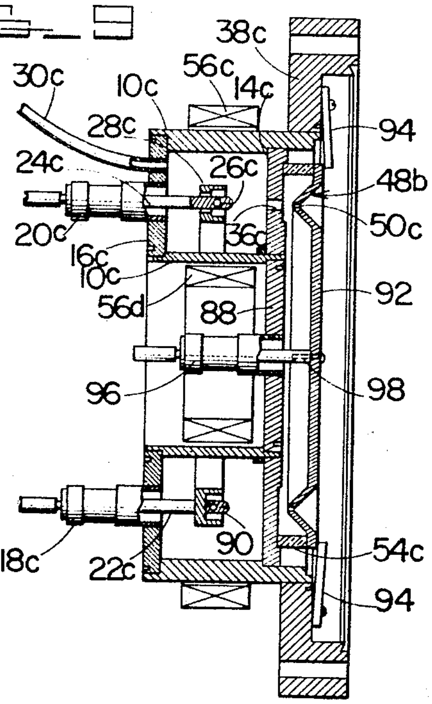


FIG. 9



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ION GUN IMPROVEMENTS FOR OPERATION IN THE MICRON PRESSURE RANGE AND UTILIZING A DIFFUSE DISCHARGE

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U.S. Cl. 313—63 18 Claims

ABSTRACT OF THE DISCLOSURE

This invention relates to an ion gun which includes a plasma chamber having a cathode disposed therein. An anode defines the chamber and contains an ion-transmitting orifice in one end thereof. An ion-extracting electrode is disposed adjacent to this orifice on the side opposite the chamber. The ion-extracting electrode has a beam-defining aperture oppoiste the orifice, which, in conjunction therewith, provides an electrostatic field for forming and directing a beam of ions from the chamber through both said orifice and aperture. Between the anode and ion-extracting electrode is a region-enclosing wall having openings at its opposite ends, these openings being the orifice and aperture, respectively. This region thus defined inhibits the escape of neutral gas so as to provide an increase in operating efficiency. Electrons issuing from the cathode ionize neutral gas within the chamber to form a plasma. By reason of the optics formed by the orifice and aperture, ions are extracted from the plasma, formed into a beam and discharged through the aperture in this form for subsequent utilization.

The present invention relates to an ion gun improvement, and more particularly to ion guns operated at relatively low gas pressures and utilizing electron discharges for the creation of ions. One of the most popular devices for the development of ion beams includes the duoplasmatron which accomplishes the two basic requirements of forming a plasma and extracting ions from the plasma. In the duoplasmatron, the plasma is produced in a few hundred microns pressure by a concentrated arc discharge immediately adjacent to an exit aperture. On the high vacuum side of this aperture, an extractor accelerates ions from the plasma and concentrates them into a beam, which is then formed and accelerated for the particular application. A high degree of ionization is achieved in the concentrated arc which makes it possible to obtain high gas efficiencies. However, the high energy densities in the chamber where ionization occurs results in intense wall heating of the vessel and bombardment with associated impurity liberation. As a consequence, performance characteristics are necessarily limited.

This invention makes use of a diffuse, filament-excited discharge operating in the micron pressure range. This leads to great reduction of the energy density at the walls surrounding the discharge, thereby minimizing heating. In this arrangement, a relatively large exit aperture is used to extract a large number of ions from the plasma. In addition to this, this aperture can be enlarged effectively by the use of an extraction electrode which contributes to the development of an electric field which reaches through the aperture into a plasma chamber. By providing appropriate electrostatic focusing, the ions removed from the plasma are drawn into a fine beam which exits through a small aperture in the extraction electrode for subsequent usage. By incorporating the extraction electrode as a part of the discharge chamber, the small aperture therein becomes the only path for ion or neutral gas flow from the chamber. In this manner, low neutral gas flow, i.e., a relatively high gas efficiency, is thus achieved.

It is therefore an object of this invention to provide an ion gun which uses relatively low gas pressures in connection with the development of a plasma from which one or more ion beams may be formed.

It is yet another object of this invention to provide an ion gun in which an extraction electrode with a small exit aperture is incorporated as a part of the ion production chamber in order to achieve a high ratio of ion output to neutral gas leakage.

It is yet another object of this invention to provide an ion gun wherein electron flow between cathode and anode electrodes follows relatively long paths through a plasma chamber such that the probability of ionization of neutral gas within this chamber is high. As a corollary of this object, there is provided means for lengthening normal straight line flow within such a chamber so as to increase significantly the probability of ionization.

It is still another object of this invention to provide an ion gun which is simple in design, inexpensive to build and maintain, and reliable in operation.

In the accomplishment of the aforesaid objectives, there is provided an ion gun comprising a plasma chamber having an electron-emitting electrode, or cathode, therein. An electron-collecting electrode, or anode, is incorporated as the chamber wall and is spaced from the cathode. An ion-transmitting orifice is provided in the vessel which encloses the chamber, and an ion-extracting electrode is disposed adjacent to this orifice on the side thereof opposite the chamber. The ion-extracting electrode has a beam-defining aperture opposite said orifice which, in conjunction with the orifice, provides ion-optical means for forming and directing a beam of ions from said chamber through both said orifice and aperture. Means is provided for introducing into the chamber a quantity of gas in the micron pressure regions, and an enclosed region between the orifice and aperture aforementioned is provided which inhibits the escape of neutral gas therefrom so as to provide an increase in gas efficiency. Electrons issuing from the cathode ionize neutral gas within the chamber to form a plasma. By reason of the optics formed between the orifice and aperture, ions are extracted from the plasma, formed into a beam, and discharged through the aperture in this form for subsequent utilization.

The above-mentioned and other features and objects of this invention and the manner of attaining them will become more apparent and the invention itself will be best understood by reference to the following description of an embodiment of the invention taken in conjunction with the accompanying drawings, wherein:

FIG. 1 is a axial sectional view, partly diagrammed, of one embodiment of this invention;

FIG. 2 is an end view thereof;

FIG. 3 is an axial section of the orifice and aperture portions of the embodiment of FIG. 1 used in explaining the ion optics involved;

FIG. 4 is an enlarged fragmentary axial section of the arrangement of FIG. 1 used in explaining the magnetic influence on electrons flowing from the cathode to the anode;

FIG. 5 is an end view of another embodiment of this invention;

FIG. 6 is a cross-sectional view taken substantially along section line **6—6** of FIG. 5;

FIG. 7 is a longitudinal view of a portion of another embodiment of this invention;

FIG. 8 is an end view of still a further embodiment of this invention; and

FIG. 9 is a cross-sectional view taken substantially along section line **9—9** of FIG. 8.

Referring to the drawings, a hermetically sealed envelope is provided in the form of tubular anode **10** having opposite end closures **12** and **14** as shown. The end closure **12** consists of a suitable strong metal plate **16** sealed to the left-hand end of the anode **10** and provided with feed-through insulators **18** and **20** which mount two conductive supporting bars **22** and **24** as shown. The mounting of these supporting bars **22** and **24** within the insulators **18** and **20** is conventional and is suitably rigid for supporting a thermionic, tungsten filament **26** on the inner ends thereof. Conductively connected to the end of the bar **22** and rigidly supported thereby is a metal cup **28** having a flat bottom and a tubular wall. The filament **26** is fitted within the cup **28** with a portion thereof projecting therebeyond as shown. The cup **28** is coaxially mounted with respect to the anode **10** and is suitable radially spaced therefrom as shown. Its purpose is to inhibit electron motion to the rear of the chamber and to provide a degree of electrostatic focusing of the discharge.

Centrally of the end plate **12** is an opening into which is fitted a gas-inlet tube **30** leading from a suitable supply **32** of gas. A valve **34** is provided for controlling manually the amount of gas flowing from source **32** through tube **30** and into the interior of anode **10**.

End closure **14** is in the form of a metal plate sealed at its perimeter to and conductively connected to anode **10** and provided with an enlarged orifice. Also, it will be noted that this aperture **36** is axially opposite filament **26**. The shape of the rim of the orifice **36** may be smoothly rounded as shown but is determined by the optics of ion extraction.

Clamped onto the right-hand end of anode **10** and hermetically sealed thereto is an extractor assembly indicated generally by numeral **38**. This assembly includes two feed-through insulators **40** and **42** having rigid bar-like conductors **44** and **46** which extend radially inwardly toward the axis of anode **10**. These rods **44** and **46** serve as voltage supply conductors as well as rigid mounts for an extractor **48** which is conically shaped in this embodiment and which is coaxially positioned as shown with respect to the orifice **36**. The apex portion of the extractor **48** is provided with an aperture **50** which is much smaller than the orifice **36** but is positioned adjacent thereto. The base of extractor **48** is remote from the orifice **36**. Suitable screws **52** are used to fasten the extractor **48** to the innermost ends of the supporting bars **44** and **46**, respectively. All of these parts are made of such material and to such size as to secure them rigidly in position.

A sleeve **54** of ceramic or other suitable insulating material is coaxially disposed between the end plate **14** and the extractor **48** as shown so as to have the ends thereof closed by these members. Thus, the sleeve **54** in conjunction with the radially inner portions of end plate **14** and extractor **48** provides a gas-tight enclosure having two openings, one being the orifice **36** and the other the aperture **50**. The diameter of the sleeve **54** is intermediate that of the anode **10** and the orifice **36**, closely approximating the latter. Extractor **48** is formed preferably of metal which produces minimum sputtering or liberation of impurities under conditions of operation of this invention.

A magnetic device **56** is mounted on the outside of anode tube **10**. While different magnetic devices may be used without departing from the spirit and scope of this invention, a preferred arrangement and one which will not consume any power is a longtudinally split cylindrical permanent magnet. In the alternative, electrical focusing coils of the type conventionally used in the television are may be used. In any event, the arrangement of the device **56** is to have the axis of polarization thereof coincident with the axis of the anode tube **10**. A magnet capable of providing a field strength within the anode tube **10** of the order of a few hundred Gauss is all that is required. As will appear from the description that follows, the present invention will work without the magnetic device **56**; however, efficiency is generally improved by the use of magnets.

In dashed lines, and indicated by the numeral **58**, is a typical evacuated chamber hermetically sealed to the right-hand end of the gun assembly described thus far, this chamber opening into and being in communication with extractor **48**. A typical vacuum pump **60** may be connecetd to chamber **58** so as to reduce the pressure therein.

A transformer **62** is connected to the filament terminals as shown, the secondary winding of this transformer being center-tapped and connected to the negative terminal of a battery **64** having the positive side grounded. Anode **10** is also grounded as shown. The filament cup **28** is at the same potential as one side of the filament **26** by reason of the conductive connection to the bar **22**.

The extractor **48** is insulated from all of the other parts of the gun, including the anode **10** and filament **26**, and has the negative terminal of a battery **66** connected thereto, the positive terminal of this battery being grounded.

In operation, potentials as shown are applied to the various electrodes, the filament **26** being heated to the point at which it emits electrons. Anode **10** being positive with respect to filament **26** collects electrons emitted by the latter. As viewed in FIG. 1, the electrons will be projected toward the right by reason of the attractive force of the field set up between the filament cup **28** and the anode **10**. Inasmuch as cup **28** is at the same potential as filament **26**, it will be obvious that the forces acting on the electrons emitted by the filament will cause rightward movement.

Assuming that the space within anode **10** has been evacuated to a pressure of, for example, 5×10^{-6} mm. of mercury, while the valve **34** has been turned "Off," the latter valve may be opened slightly to permit gas from the source **32** to flow into the interior of anode **10**. A pressure of greater than about 1-micron build-up within anode **10** constitutes one suitable operating parameter. Electrons flowing from filament **26** to anode **10** along various paths such as the path indicated by the dashed line **68** will collide with the neutral gas particles and cause ionization thereof. This results in the formation of a plasma within the space of anode **10** between the filament **26** and orifice **36**, this space being characterized as a plasma chamber.

The extractor **48** being highly negative with respect to anode **10** and end plate **14** will provide a field having a a pattern something like the configuration shown in FIG. 3. This field reaches into the plasma chamber and withdraws ions therefrom and concentrates them through the orifice **36** and also through aperture **50**. The shape of of this field is such that the ions are formed into a pencil-like beam having a size and shape corresponding to that of aperture **50**. Thus, the end plate **14** with the orifice **36** therein as well as the extractor **48** and its aperture **50** may be regarded as an ion lens which withdraws from the plasma chamber and forms them into a beam which is accelerated rightwardly into the evacuated chamber **58**. The path followed by the ion beam is indicated by the dashed line arrow **70** in FIG. 1.

The operation thus far has ignored the presence of the magnet **56**. It may be assumed that the magnet **56** was not being used. However, by applying magnet **56** in the position shown and described previously, flux lines are established something along the pattern shown in FIG. 4 diagrammatically. The result of these flux lines is to impart a helical or corkscrew motion to the electrons in their transit from filament **26** to the anode **10** such that the path length becomes considerably greater than the straight-line path indicated by numeral **68**. By thus imparting a helical motion, the probability of ionization becomes much greater. Thus, efficiency of ionization for a given filament power becomes greater.

For the embodiment illustrated, formation of an ion beam can be achieved through the use of a filament supply of 6-volt, 12-ampere capability. The voltage of the battery **64** is made variable between 50 and 500 volts, with 50-volts being typical for operation. Battery **66** similarly is preferably variable, a typical setting being 10-kilovolts.

Because the plasma from which the ions are extracted is diffuse in this invention, the plasma chamber can be constructed in various sizes. For this reason, a variety of different extraction electrode geometries can be utilized to produce other than pencil-like ion beams. As an example, hollow ion beams have been produced utilizing orifices and extractors with circular slot geometry. A straight slot arrangement will provide a sheet-like beam. A number of pencil beams can be produced from an arrangement utilizing a number of similar extraction chambers disposed on the anode of the plasma chamber. Examples of these will be described hereinafter.

In the operating embodiment described herein, deuterium gas was utilized to provide deuterium ions. A variety of other gases such as oxygen, nitrogen, helium, argon, krypton, etc. can also be utilized to provide beams of each of their ions.

Suitable dimensions and materials for an operating embodiment of this invention are given in the following, it being understood that these dimensions are given by way of example only and not by way of limitation:

Inner diameter of anode **10**	1¾ inches.
Material of anode **10**	304 stainless steel.
Orifice **36**	½ inch diameter.
Aperture **50**	.070 inch diameter.
Approximate length of plasma chamber between filament **26** and end plate **14**	2 inches.
Spacing between end plate **14** and apex of extractor **48**	⅛ inch.
Axial dimension of extractor **48**	½ inch.
Gas in the source **32**	Deuterium.
Range of operating pressures	10^{-3} to 10^{-2} mm. of mercury.
Cathode filament	2% thoriated tungsten wire 0.012 inch dia. by ¾ inch long.

Operation of the invention may be further considered with respect to two different modes of operation, one being the ignited and the other the unignited. Initiation of the ignited mode occurs above about 1-micron of deuterium and −50 volts on the filament assembly. In the operating region, the current drawn by the discharge is solely determined by the filament emission. In the unignited mode, currents are limited to the order of milliamperes.

Based on the data given hereinabove, a 10-milliampere ion output can be generated and extracted at minus 50 (−50) volts on the filament assembly with 400-milliamperes current. 12-kilovolts is used on the extractor **48**. These conditions require of the order of 5-volts to the filament **26**, the total power required for this output being of the order of 100-watts. This compares favorably with the order of 1,000-watts required for the same current from a duoplasmatron. Since the parts of this invention do not require extensive machining, the device is relatively simple and comparatively inexpensive to construct. Maintenance is confined to filament replacement, and at operations below 1-ampere filament replacement is indeed rare. The exit aperture of .070 inch used in this invention represents 100 times the area of the .007 inch diameter apertures typical of the duoplasmatron. However, the fact of the present invention operating at a much reduced pressure over that of the duoplasmatron results in substantially decreased, neutral gas leakage.

Gas efficiencies defined as the ion beam current divided by the number of particles (both neutrals and ions) passing through the aperture **50** are high in this invention, a part of this greater efficiency being attributable to the fact that the insulating sleeve **54** prevents escape of neutral molecules around the sides of the extractor **48** and into the evacuated chamber **58**. Thus, neutral gas is restricted in the escape paths thereof which necessarily results in their being retained in or near the space of the plasma chamber thereby undergoing the greater probability of being ionized. Such paths are limited transversely by the sleeve **54** which is of a diameter intermediate the diameters of the anode **10** and the orifice **36**, thereby maintaining the neutral gas in a space close to the orifice **10**, so that it may penetrate into the chamber inside the anode **10**, and also close to the ion beam which penetrates aperture **50**. All of these factors contribute in this invention in the creation of higher output currents as well as greater efficiencies.

Referring to FIGS. 5 and 6, a different embodiment will be described in which a plurality of ion beams may be formed from a single gun structure. In these figures, similar parts are indicated by like numerals with the suffix "*a*" added. The cathode cup **28*a*** is annular in this embodiment, rather than circular as the cup **28** shown in FIG. 1. The filament **26*a*** disposed therein is in the form of two concentric rings **70** and **72**, respectively. These two rings are conductively connected together by means of a radially extending supporting bar **74** or the like (FIG. 5) and to the cup **28*a*** such that filament voltage applied to the ring **70** and to the cup **28*a*** may also be conducted to the ring **72**.

A secure connection of the ring **70** to the supporting bar **24*a*** is made by some suitable means such as spot welding. The bar **24*a*** passes through a clearance opening in the cup **28*a***. The other supporting bar **22*a*** is press-fitted or otherwise securely conductively connected to the cup **28*a***. By this means, the cup **28*a***, which is generally flat, as well as the filament structure **26*a***, in positioned substantially parallel to the end plate **16*a*** and furthermore is disposed substantially coaxially inside the anode **10*a***.

The end closure **14*a*** has a multiplicity of orifices **36*a*** spaced apart in a circular pattern as shown. There are two circular series of these orifices **36*a*** concentrically arranged and positioned substantially opposite the two filament rings **70** and **70*a***.

Mounted in spaced relation with respect to the end closure **14*a*** is a metal plate or carrier **76** having a multiplicity of ion-extracting electrodes **48*a*** formed therein. Each of the electrodes **48*a*** has an aperture **50*a*** in registry with respective orifice **36*a***. Suffice it to say, any single combination of an orifice **36*a*** and extracting electrode **48*a*** is the same as the orifice and extracting electrode already described in connection with the arrangement of FIG. 1.

The plate **76** is positioned in parallelism with the end closure **14*a*** on one side by the tubular member **54*a*** of insulating material which is closed at its right-hand end by the plate **76** and its left-hand end by the end closure **14*a***. At diametrically opposite points on the outer peripheral portion thereof, the plate **76** is engaged by two brackets **78** of insulating material which are fixedly attached to the end assembly **38*a*** on the anode **10*a***. Thus, plate **76** is rigidly held in position and, furthermore, it is insulated from anode **10*a***. A conventional feed-through insulator **80** is hermetically sealed to the end closure **16*a*** and axially penetrates the entire assembly to be connected to the plate **76**. This feed-through insulator **80** includes a sleeve **82** of insulating material and a central conductor **84** conductively connected at the right-hand end thereof to the plate **76**. By means of this feed-through insulator **80**, the necessary supply voltage may be coupled to the plate **76**. Gas is admitted to the device by means of the inlet line **30*a*** affixed to the end **16*a***.

Operation of this device is essentially the same as described previously in connection with the embodiment of FIG. 1, suitable exciting voltage being applied to filament **26***a* which in turn emits electrons eventually collected by anode **10***a* or the end closure **14***a*. Collision of these electrons with neutral atoms and molecules of gas within the chamber formed between filament **26***a* and closure **14***a* results in formation of the plasma from which beams are extracted by means of orifice **36***a* and related extractors. Instead of forming a single beam, as in the case of the embodiment of FIG. 1, this arrangement is capable of forming and emitting a multiplicity of beams. Magnets, such as magnets **56** of FIG. 1, may or may not be used, as desired, with this arrangement of FIGS. 5 and 6. Voltage is applied to extractors **48***a* by means of the plate **76**.

Referring next to FIG. 7, a still further embodiment of this invention is illustrated. In this figure, like numerals indicate like parts with certain structure which is merely duplicative of that shown in FIG. 1 being omitted for clarity. The primary difference between the designs of FIGS. 7 and 1 resides in the configuration of the ion optics located at the right-hand end of the anode tube **10**. As shown, anode tube **10** has an end closure **14***b* provided with an orifice **36***b* of annular shape. Radial bar-like support members (not shown) extending across orifice **36***b* locate and hold the central portion **86** of end closure **14***b* in position. These radial supports are of minimal size so as to provide maximum openness of the orifice **36***b*.

The ion-extracting electrode **48***b* is also of annular shape and in radial cross-section appears to be generally triangular as shown. In the apex of the triangle is provided the aperture **50***b* which for the total ion-extracting electrode **48***b* is annular. Aperture **50***b* is located axially opposite the annular orifice **36***b*. Insulating sleeve **54***b* is located between end plate **14***b* and extractor **48***b* and furthermore is situated peripherally outside the orifice and aperture. In operation, instead of a beam of solid, pencil-like cross-section, a hollow beam is formed. The principles and theories already explained in connection with FIG. 1 are equally applicable here in forming the beam. Close examination of orifice **36***b* will reveal that its cross-sectional shape is somewhat different than that of orifice **36** in FIG. 1 and **36***a* in FIG. 6. Suffice it to say, the shapes used will be those required in forming the necessary ion optical effect which will form the beam shape and size desired. More specifically, the orifice **36***b* is formed with a taper as shown which opens toward the triangular portion of the extractor **48***b*.

Another embodiment for forming an annular beam is shown in FIGS. 8 and 9, wherein the plasma chamber is of annular shape rather than cylindrical, as is true of the preceding embodiments. Bounding this annular chamber is the anode structure which comprises an outer anode sleeve **10***c* and an inner anode sleeve **10***d*. An annular end plate **16***c* closes the left-hand end of the chamber while another annular end plate **14***c* closes the right-hand end. The plate **14***c* is provided with an annular orifice **36***c* which is coaxial with respect to all of the other structure in the assembly.

Another closure plate **88** covers the right-hand end of the anode sleeve **10***d* and is secured in such a manner as to provide an hermetic seal. The two plates **14***c* and **88** may be regarded as a single disc when considering the operation of this embodiment.

A ring filament **26c** is disposed coaxially within the chamber between the two anode sleeves **10***c* and **10***d* and furthermore is axially opposite the annular orifice **36***c*.

Coaxially mounted also in the assembly is a cathode cup **28***c* of annular shape within which the ring filament **26***c* is positioned. The supporting bar **24***c* of the feed-through insulator **20***c* is directly secured conductively to ring filament **26c** as shown and passes through an enlarged hole within the cup **28***c* as shown to provide insulation. The other supporting bar **22***c* is secured directly to the bottom of cup **28***c* as shown and the filament **26***c* in turn is secured to a small post **90** upstanding from the bottom of cup **28***c* for holding the filament in position and providing a conductive connection thereto.

A flat, metal plate **92** has the extractor **48***b* formed therein, the latter being of annular shape and positioned in registry with respect to the orifice **36***c*. In radial cross-section, the extractor **48***b* is triangular with an annular orifice **50***c* being provided in the apex thereof. The orifice **36***c* and aperture **50***c* are in axial registry the same as is true of the preceding embodiments.

The sleeve **54***c* is interposed between and closed by end plate **14***c* and the outer peripheral portion of plate **92** as shown. For securing plate **92** in position, two insulating bars **94** secured to the anode flange part **38***c* and clamped against plate **92** are used as shown.

For providing an electrical connection to plate **92**, a centrally disposed feed-through insulator **96** is used, this insulator **96** being attached to the supporting plate **88** with the center conductor **98** thereof being connected at its right-hand end to plate **92**. The gas inlet tube **30***c* is secured to plate **16***c* and serves in feeding neutral gas to the plasma chamber.

In operation, potentials are applied in the same manner as previously described, setting up an ion optical effect between orifice **36***c* and aperture **50***c* whereby ions in the plasma between filament **26***c* and orifice **36***c* are extracted therefrom and formed into an annular beam. A magnet assembly **56***c* and **56***d* mounted on the outside of sleeve **10***c* and on the inside of sleeve **10***d*, respectively, is so polarized as to have an axis of polarization coaxially of the plasma chamber and coincident with a line drawn between filament **26***c* and aperture **50***c*. The field produced by these magnets lengthens the transit of electrons from filament **26***c* to anode **10***c*, **10***d*, **14***c* such that the probability of ionization is greater than would be true without the magnets being present. However, as stated previously, the device will function as an ion gun without the magnets, but efficiency is markedly increased by having the magnets in the assembly.

While there have been described above the principles of this invention in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation to the scope of the invention.

What is claimed is:

1. An ion gun comprising first means providing a plasma chamber, an electron-emitting electrode in said chamber, said first means including an electron collecting electrode spaced from said electron-emitting electrode in said chamber, an ion-transmitting orifice in said first means communicating with said chamber, second means including said electrodes for directing electrons through the space of said chamber, means for introducing neutral gas into said chamber, an ion-extracting electrode disposed adjacent said orifice on the side thereof opposite said chamber, said ion-extracting electrode having a beam-forming aperture opposite said orifice, ion-optical means including said orifice and said ion-extracting electrode for forming and directing a beam of ions from said chamber through both said orifice and aperture, and means for defining an enclosed region between said orifice and said aperture from which escape of neutral gas is inhibited, said enclosed region being peripherally defined by a wall disposed immediately adjacent to the outermost edge of said orifice, the transverse dimension of said region being smaller than said chamber and larger than said orifice.

2. The ion gun of claim **1** wherein said chamber is hermetically sealed for the maintenance therein of gas at sub-atmospheric pressure, said electron-emitting electrode being a filament, said chamber enclosing said filament and including said orifice, and means at a more negative potential than said electron-collecting electrode for directing flow of electrons from said filament in a direction into said chamber.

3. The ion gun of claim 1 wherein said chamber is hermetically sealed for the maintenance therein of gas at sub-atmospheric presure, said electron-emitting electrode being a filament, said chamber enclosing said filament and including said orifice, said orifice being larger than said aperture, and means for applying a unidirectional potential to said ion-extracting electrode which is negative with respect to said electron-collecting electrode.

4. The ion gun of claim 3 wherein said electron-collecting electrode includes a tubular anode having end closures, said anode surrounding said chamber, said orifice being in one end closure, said wall being of a diameter intermediate the diameters of said anode and said orifice, said orifice being in one end closure, said one end closure being conductive, and said ion-extracting electrode being insulated from said one end closure.

5. The ion gun of claim 4 in which said ion-extracting electrode is a cone shaped conductive member coaxially disposed with respect to said orifice and with the apex portion thereof next adjacent to said orifice, said aperture being in the apex portion of said member, said wall including a tubular member of insulating material coaxially disposed between and being closed at its opposite ends by said cone shaped member and said one end closure, respectively.

6. The device of claim 5 wherein said filament is positioned in the end portion of said tubular anode opposite from said orifice, and a magnet device is disposed to provide a magnetic field for imparting a spiraling motion to electrons in transit from said filament to said anode.

7. The device of claim 6 in which said magnet device is disposed on the outside of said anode, said magnet device having opposite ends polarized oppositely, said polarized ends being spaced apart in a direction parallel to the axis of said anode, and said orifice and aperture being coaxially located with respect to said anode.

8. The device of claim 7 including an element for establishing an electric field on the side of said filament opposite from said orifice such that electrons emitted by said filament will flow through said chamber and towards said anode.

9. The device of claim 8 in which said electric-field element includes a plate-like member disposed transversely of said anode on the side of said filament opposite said orifice, said plate-like member being conductively connected to said filament.

10. The device of claim 1 including means for maintaining the gas within said chamber at sub-atmospheric pressure in the range of about 10^{-3} to 10^{-2} millimeters of mercury.

11. The ion gun of claim 4 in which said ion-extracting electrode is a cone shaped conductive member coaxially disposed with respect to said orifice and with the apex portion thereof next adjacent to said orifice, said aperture being in the apex portion of said member, said member being mounted on a plate-like carrier which extends radially from the base portion thereof, said region-defining means being a tubular wall of insulating material disposed between and being closed at its opposite ends by said carrier and said one end closure, respectively.

12. The device of claim 11 in which said one end closure has a plurality of orifices therethrough, said carrier being a conductive plate having a plurality of ion-extracting electrodes thereon in registry with all of said orifices, respectively, said carrier having a peripheral portion which engages and closes one end of said insulating member, said carrier being insulated from said anode and said one end closure.

13. The device of claim 12 in which said orifices and extracting electrodes are arranged in a pattern of two concentric circles, said filament being generally circular and disposed axially opposite said orifices.

14. The device of claim 4 in which both said orifice and said ion-extracting electrode are annular shaped and coaxially positioned with respect to each other, said ion-extracting electrode in radial section being generally triangular with its apex portion next adjacent to said orifice, said aperture being annular and in the apex portion of said ion-extracting electrode, said region-refining means being a tubular member of insulating material coaxially disposed between and being closed at its opposite ends by said ion-extracting electrode and said one end closure, respectively.

15. The device of claim 14 in which said chamber is of annular shape bounded on the inner and outer sides by said tubular anode, said anode including two coaxially disposed cylindrical sleeves.

16. The device of claim 15 in which said ion-extracting electrode is a part of a disc of conductive material, and a feedthrough insulator secured to said one end closure and having a centrally disposed conductive supporting bar secured at one end to said disc and extending axially through and being insulated from said one end closure.

17. The device of claim 16 in which a magnet assembly is disposed on the inner and outer peripheral sides of said inner and outer sleeves, said magnet assembly having an axis of polarization extending axially with respect to said chamber and a field which penetrates said chamber and controls the paths followed by the electrons in the transit thereof from the filament to said anode.

18. The device of claim 16 in which said filament is of annular shape disposed coaxially within said chamber axially opposite said annular orifice, and a cathode cup of annular shape within said chamber and opening toward said annular orifice, said annular filament being coaxially disposed within and conductively connected to said cup, and means fixedly supporting said cup in position in insulated relation with respect to said anode whereby an electric field may be established which directs electrons emitted by said filament away from said cup and toward said anode.

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