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ION SOURCE HAVING AN EXPANSION CUP
FOR EFFECTING BEAM DIVERGENCE
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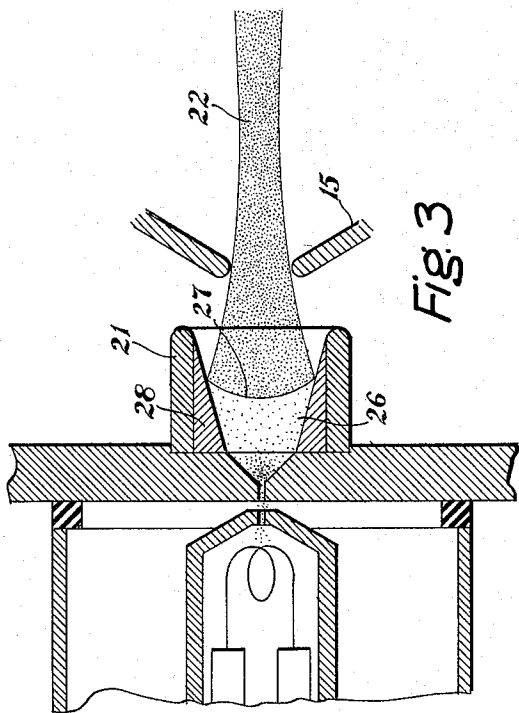


Fig. 3

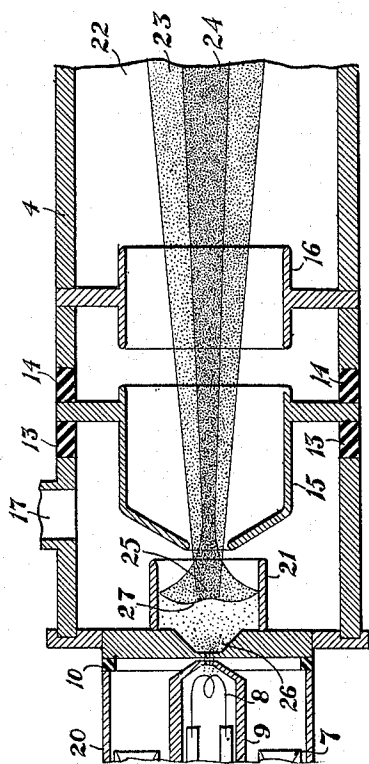


Fig. 1

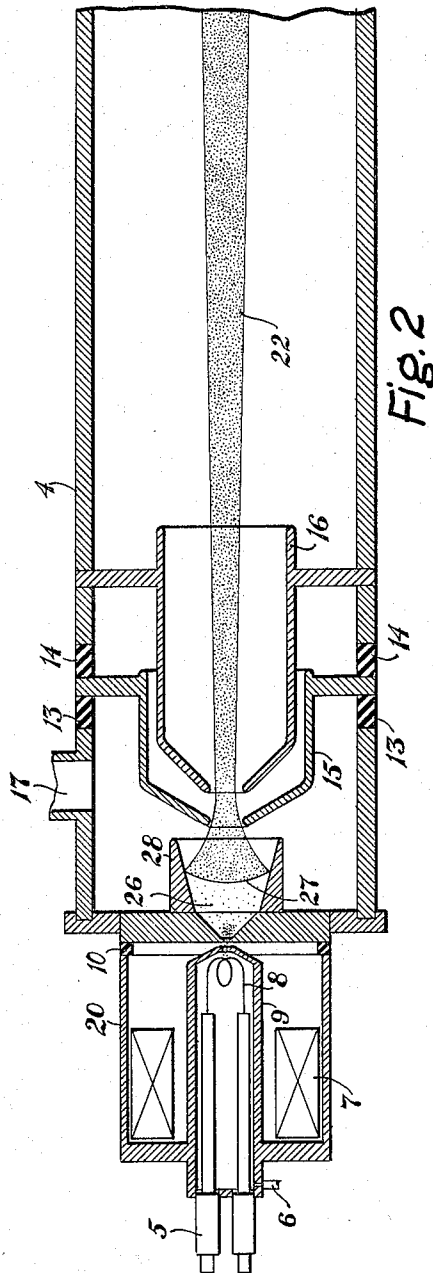


Fig. 2

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ION SOURCE HAVING AN EXPANSION CUP FOR EFFECTING BEAM DIVERGENCE**Norman B. Brooks, Carlisle, Mass., assignor to High Voltage Engineering Corporation, Burlington, Mass., a corporation of Massachusetts**

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4 Claims. (Cl. 315—111)

This invention relates to the generation of low divergence, high intensity ion beams and in particular to means for controlling the plasma boundary of an ion source in such a way as to effect improved beam divergence characteristics.

Ion sources of the type comprehended by this invention are described in detail in the copending patent application of Andrew Wittkower for Ion Source, Serial Number 205,168, filed June 18, 1962, and assigned to the assignee of the present patent application. In general, the ion source disclosed by Wittkower introduces new concepts of ion extraction from the gas ionization chamber. That is, Wittkower has recognized that for any ion beam of given parameters there exists an optimum plasma boundary area that will result in minimum beam divergence. He has therefore provided, beyond the anode extraction aperture, a plasma drift space of enlarged area adapted to permit plasma expansion and to present to the extraction electrode a plasma boundary of the desired area. Inasmuch as such an arrangement retains the conventional small anode extraction aperture through which ions are extracted from the gas ionization chamber, no large unwanted amounts of gas escape into the ion source vacuum system.

In addition to the above noted improvements disclosed by Wittkower, further optimization of beam divergence can be achieved if the plasma boundary can be made to assume a uniform concave surface. The conventional ion source utilizes a magnetic field to concentrate the plasma in the vicinity of the anode extraction aperture. The magnetic field lines, to some extent, extend through the aperture and effect concentration of ions on the beam axis thus establishing a concomitant non-uniform plasma boundary surface. Because of the density and the high energy of the extracted ion beam, it is undesirable to counteract this effect by the use of a grid.

Accordingly, it is a principal object of this invention to provide means for producing an improved low divergence, high intensity ion beam.

It is another object of this invention to establish, in an ion source of the type described, a uniform concave plasma boundary.

Still another object of this invention is to provide, in an ion source of the type described, a plasma expansion cup having a particular geometry adapted to concentrate the extraction field along the axis of the ion beam so as to oppose the magnetic field effect on the plasma boundary.

These, together with other objects and features of the invention will become more readily apparent from the following detailed description thereof taken in conjunction with the accompanying drawings wherein like elements are given like reference numerals throughout and in which:

FIGURE 1 is a partial section of an ion source illustrating the non-uniform plasma boundary and beam divergence typical of prior art devices;

FIGURE 2 is a partial section of an ion source employing the principles of this invention; and

FIGURE 3 is a detail of the plasma expansion cup and plasma boundary area of FIGURE 2.

Referring now to FIGURE 1 there is illustrated thereby an ion source of the type to which this invention can be applied. In operation, hydrogen gas is injected into ionization chamber 20 by means of gas input conduit 6. Probe 9 is centrally positioned in ionization chamber 20 and has a filament 8 disposed therein. Filament supply 5 maintains filament 8 at a negative voltage with respect to anode 11. Probe 9 is maintained at an intermediate voltage between filament 8 and anode 11. Magnet coil 7 shapes the discharge arc between filament 8 and anode 11 and concentrates the ions which are formed by such discharge in the presence of hydrogen gas, in the anode aperture region. Ions produced in ionization chamber 20 are drawn therefrom through the anode aperture by extractor electrode 15. Plasma expansion cup 21 permits plasma passing through the anode aperture to expand and present a predetermined optimum boundary area to extraction electrode 15. Extraction electrode 15 is maintained at a negative potential with respect to anode 11 and is aligned to direct ions extracted from plasma expansion cup 21 to focusing electrode 16. Electrodes 15 and 16 are disposed within ion beam forming chamber 4 and are electrically isolated by insulators 10, 13 and 14.

Ion beam 22 is extracted from the plasma residing in plasma expansion cup 21 by applying a voltage gradient between plasma expansion cup 21 and extractor electrode 15. The field lines formed by this extraction mechanism form a lens through which the extracted beam must pass. The diameter and divergence of the ion beam are determined by the field shape, the strength of the extraction field, and the beam intensity. The field shape depends on the geometry of the electrodes and also on the shape of plasma boundary 27. Plasma boundary 27, which is the interface between the plasma and beam 22, behaves somewhat like an elastic membrane balanced on one side by the pressure of the plasma and on the other by the pressure exerted by the electric field lines.

Devices of the type disclosed by FIGURE 1 produce a beam that consists of a core component 24 of high current density and low angular divergence superimposed upon a beam component 23 of low current density and high angular divergence. Beam component 23 appears as a "halo" around the bright core component 24. The formation of such a "halo" is of considerable importance and its presence constitutes an appreciable loss of usable beam current. Although the current density within this portion of the beam is low, the "halo" radius is much larger than the core radius and therefore, the total intensity within the "halo" may be as great or greater than in the low divergence core component.

The "halo" effect of such a prior art ion source is essentially a function of the plasma boundary configuration. The plasma is pinched along the axis at the anode aperture by the magnetic field of magnet coil 7. Some of these field lines extend through the aperture and as a result at the plasma boundary there is a concentration of the ion density on the beam axis. If the concept of the plasma boundary as an elastic membrane is again considered, it can be visualized that because of the greater plasma density the plasma boundary will exhibit a convex protrusion 25 on the axis. The low divergence core, then, is formed by particles leaving the outer concave portion of the plasma boundary. On the other hand, particles leaving convex protrusion 25 diverge rapidly to form the part of the beam observed as the "halo."

Having reference now to FIGURES 2 and 3, there is illustrated a modification of plasma expansion cup 21 that has the effect of eliminating the undesirable "halo." By means of tapered annular insert 28 a uniform concave plasma boundary 27 is provided which concomitantly produces a low divergence uniform beam. Thus, in ac-

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cordance with the principles of the invention the extraction field is concentrated on the beam axis by expanding the plasma into the frustum shaped expansion space established by insert 28. The increased axial electric field strength produced by this configuration has the effect of pushing the center portion of the plasma boundary back so that it forms part of the concave surface. By analogy with light optics, the "figure" of the whole plasma boundary thus determines the quality of the extracted beam. By use of this frustum shaped plasma expansion space, the beam is always observed to have considerably less "halo" and, by adjustment of the source density, a condition can be arranged whereby no "halo" whatever is visible.

While it has been shown and described what is considered at present to be a preferred embodiment of the invention, modifications thereto will readily occur to those skilled in the art. For example, an insert 28 having a convex or concave taper might be preferable to the linear taper disclosed herein for certain beam parameters. Furthermore, since the effect of insert 28 is to shape the extraction field in the vicinity of the plasma boundary any means for so shaping said extraction field for the purpose of effecting a given plasma boundary configuration is deemed to be comprehended by the invention.

It is not therefore desired that the invention be limited to the specific arrangement shown and described, and it is intended to cover in the appended claims all such modifications that fall within the true spirit and scope of the invention.

What is claimed is:

1. An ion source comprising an ionization chamber, means for supplying thereto a quantity of gas to be ionized, means for ionizing said gas, an evacuated plasma forming chamber, an apertured anode member, an extractor electrode at a high potential with respect to that of said anode member, said anode member comprising a common partition between said ionization chamber and said evacuated plasma forming chamber, said anode member having an aperture therein of a size commensurate to the ion beam current requirements of said ion source, said ion source producing a concentration of ions at said aperture sufficiently great so that there would be a tendency for space charge repulsion to produce a highly divergent beam upon extraction of positive ions at that point, a cylindrical member contiguous to and coaxially aligned with the aperture in said anode member and protruding into said ion beam forming chamber, said cylindrical member being at the same electrical potential as that of said anode member and being of sufficient length to form a region free of influence of the field effect of the extractor electrode

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until such time as said plasma has diffused to a sufficient extent to reduce space charge effects in the ion beam to be extracted therefrom, said cylindrical member thus providing a drift space adapted to allow expansion of plasma passing therethrough and having the shape of a frustum whose diameter increases in the direction away from said plasma forming chamber, so as to establish a uniform concave plasma boundary therein, and a focusing electrode.

2. An ion source as defined in claim 1 including a plasma boundary forming grid disposed across said cylindrical member.

3. In an ion source having a gas ionization chamber and an evacuated plasma forming chamber, plasma control means comprising an anode, an extractor electrode at a high potential with respect to that of said anode, said anode constituting a common partition between said ionization chamber and said plasma forming chamber and having an aperture therein adapted to communicate a controlled quantity of ions therebetween, said ion source producing a concentration of ions at said aperture sufficiently great so that there would be a tendency for space charge repulsion to produce a highly divergent beam upon extraction of positive ions at that point, and an annular member contiguous thereto disposed in concentric relationship to said aperture, said annular member being at the same electric potential as that of said anode and being of sufficient length to form a region free of influence of the field effect of the extractor electrode until such time as said plasma has diffused to a sufficient extent to reduce space charge effects in the ion beam to be extracted therefrom, said annular member thus providing a drift space and exit aperture for said plasma and having the shape of a frustum whose diameter increases in the direction away from said plasma forming chamber, so as to establish a uniform concave plasma boundary therein.

4. Plasma control means as defined in claim 3 including a plasma boundary forming grid disposed across said annular member.

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