

[54] **LARGE DIAMETER ION BEAM
APPARATUS WITH AN APERTURED
PLATE ELECTRODE TO MAINTAIN
UNIFORM FLUX DENSITY ACROSS
THE BEAM**

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[58] Field of Search **250/41.92, 41.9 SB**

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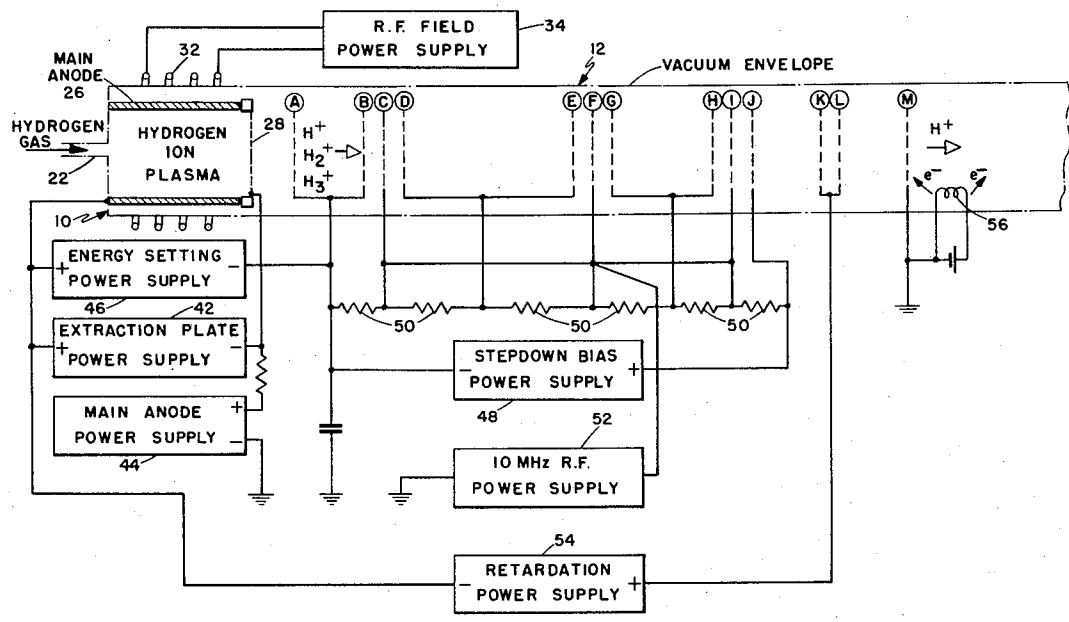
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[57] **ABSTRACT**

The apparatus generates a high energy beam of large size, on the order of 12 centimeters or more in diameter, the beam being passed through a mass separator which extracts unwanted charged particles, leaving a pure single specie beam. The resultant beam is space charge neutralized to prevent coulombic spreading and maintains a substantially constant flux density over the full beam cross section. Using appropriate gaseous material for ionization, the apparatus provides a particularly effective simulation of solar plasma wind, as one example of its utility.

4 Claims, 4 Drawing Figures



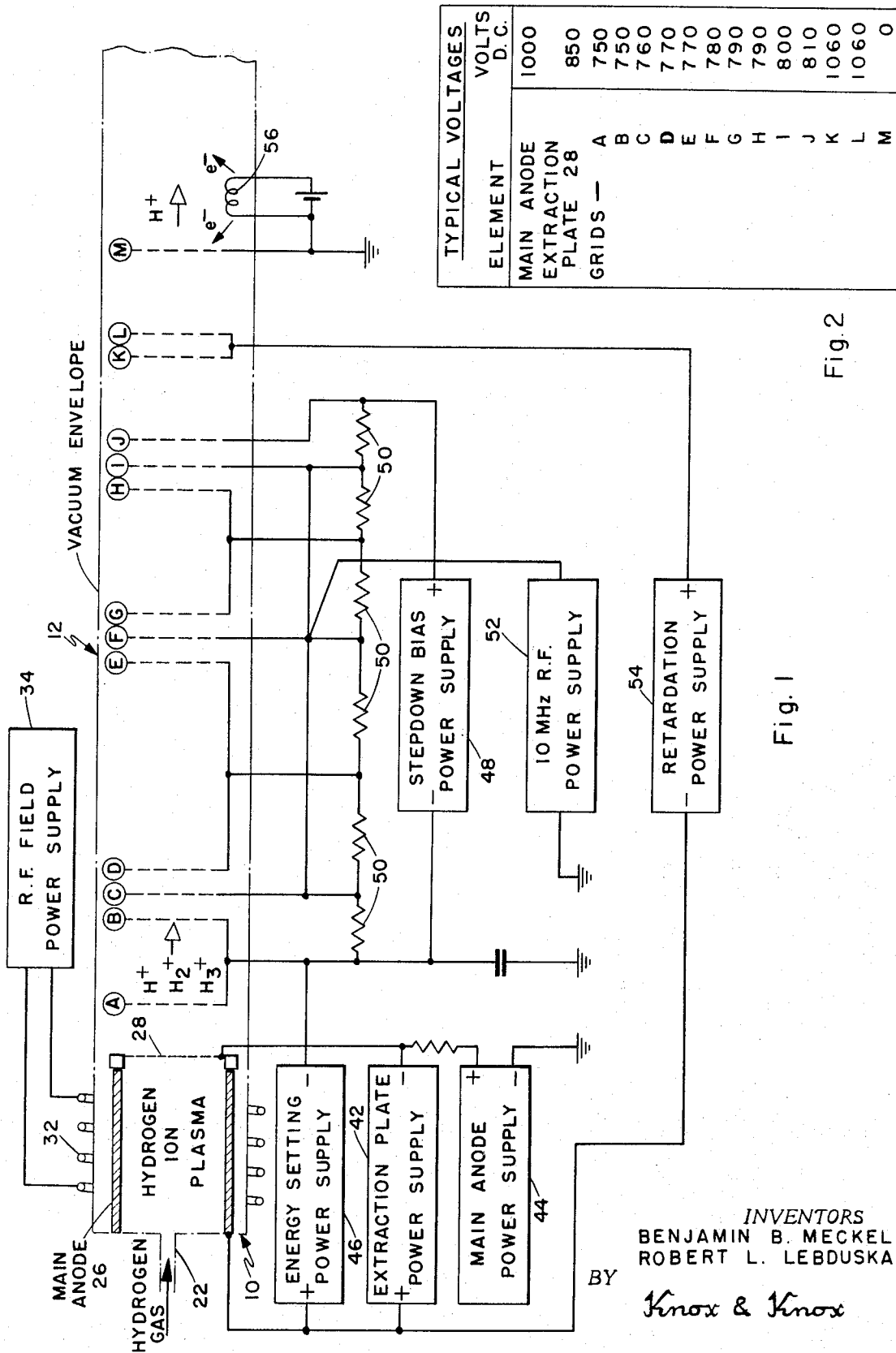
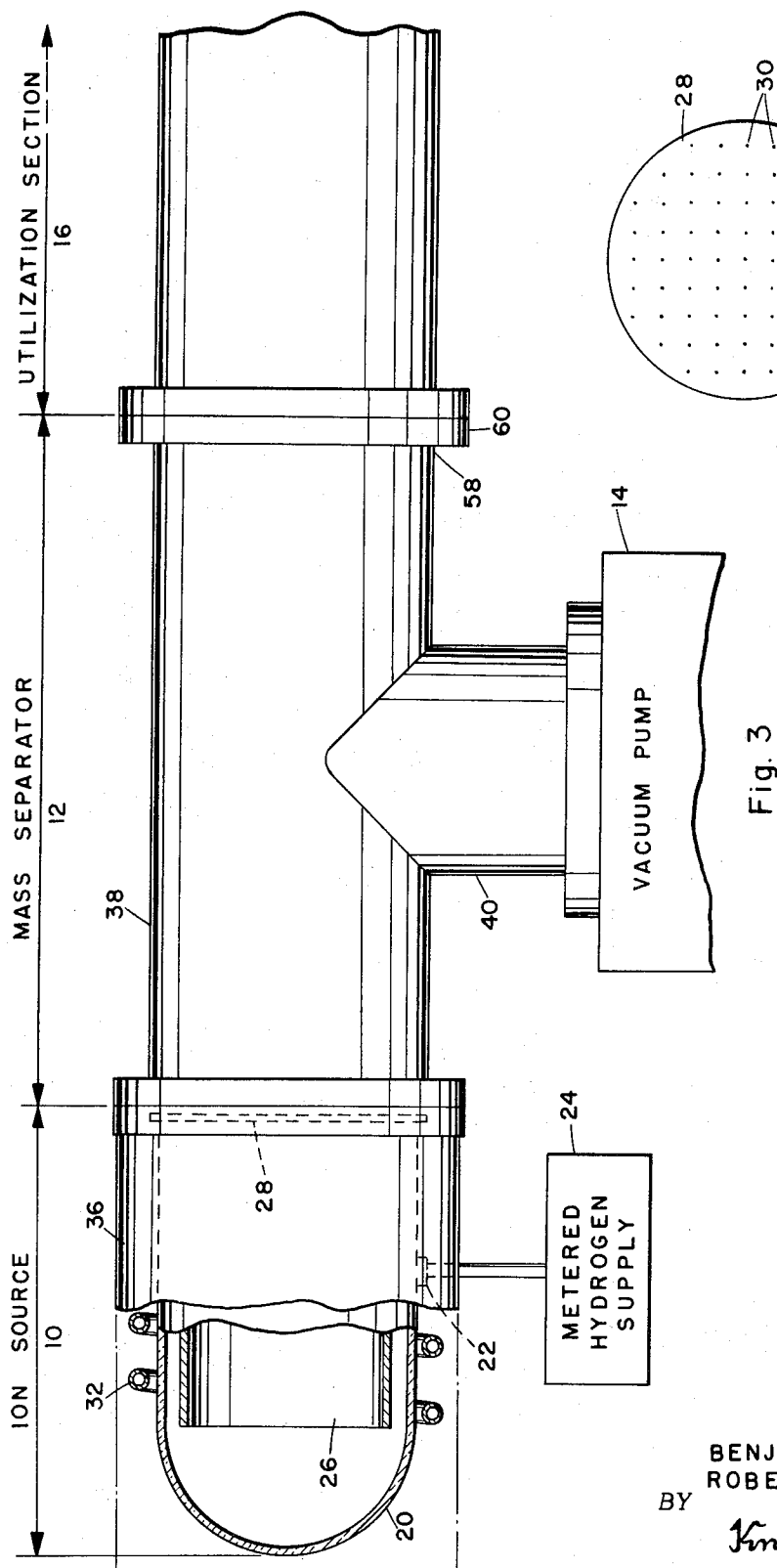


Fig. 2

TYPICAL VOLTAGES		VOLTS D. C.
ELEMENT		
MAIN ANODE		1000
EXTRACTION		850
PLATE 28		750
	A	750
	B	760
	C	770
GRIDS —	D	770
	E	780
	F	790
	G	790
	H	800
	I	810
	J	1060
	K	1060
	L	
	M	0

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LARGE DIAMETER ION BEAM APPARATUS WITH AN APERTURED PLATE ELECTRODE TO MAINTAIN UNIFORM FLUX DENSITY ACROSS THE BEAM

BACKGROUND OF THE INVENTION

The present invention relates to charged particle beam generation and specifically to a large diameter ion beam apparatus.

In the technique of energetic beam generation, many different types of apparatus have been used to provide ion beams, plasmas and the like. For propulsion purposes nozzle-like elements have been used to form multiple discrete energy beams, having the effect of a large beam in which uniform energy distribution across the beam is not a critical factor.

For analytical use it is a well known procedure to separate various particles from a charged beam in a mass spectrometer. This usually involves a single small beam which can be suitably controlled by magnetic deflection and limited by slits.

SUMMARY OF THE INVENTION

The apparatus described herein generates a large diameter (on the order of 12 centimeters) beam of pure single species ions of substantially uniform cross-sectional flux density. Initially the ions are extracted from the generating source in a large number of closely spaced beams which merge into a single beam in passing through a mass separator. The beam is of constant diameter and the entire end of the mass separator is open to allow the full beam to be utilized. By suitably energizing the stages of the mass separator, unwanted charged particles are removed and the resultant beam contains only the single species ions required. The output beam is space charge neutralized, by injection of low energy electrons, to prevent coulombic spreading and so maintain a parallel beam of uniform characteristics.

While there are many uses for such a beam, it is significant that the space charge neutralized beam of appropriate gaseous ions closely simulates the solar plasma wind and the beam is of sufficiently large diameter to be of use in studying solar energy exposure effects on a variety of material samples.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram of the apparatus;

FIG. 2 is a table showing typical voltages used in the solar wind application of the apparatus;

FIG. 3 is a side elevation view, partially cut away, of a typical form of the apparatus; and

FIG. 4 is a face view of the beam extraction plate.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The apparatus comprises an ion source 10 coupled to a mass separator 12, with its attendant vacuum pump 14, and a utilization section 16 in which the beam is actually put to use. The entire working enclosure in which the beam is active, is, of course, maintained at high vacuum, as indicated in FIG. 1.

Ion source 10 includes a dielectric bell chamber 20, of Pyrex or the like, with an inlet 22 into which is injected a closely metered flow of the gas to be ionized, as from a gas supply source 24, various types of which are available. Within the bell chamber 20 is a main anode 26 and mounted in the open or output end of the bell chamber is a discoid extraction plate 28, which comprises the initial beam accelerating electrode. As shown in FIG. 3, the extraction plate 28 has a large number of closely spaced apertures 30 of very small size, the number, spacing and total effective open area depending on the required beam characteristics. The use of a large number of small apertures produces many small ion beams which merge effectively into a single beam without the severe space charge limitations, such as encountered with multiple nozzle elements. Surrounding the bell chamber 20 is an r.f. (radio frequency) field coil 32 energized by a conventional power supply 34, the r.f. field providing the energy to ionize the gas in the bell chamber. An r.f. shield is mounted around the ion source assembly to eliminate undesirable field effects.

The mass separator 12 is similar to a Bennett tube mass spectrometer and comprises a cylindrical casing 38 sealed in coaxial alignment to the ion source 10. Vacuum pump 14 exhausts from an outlet 40 on the side of casing 38 and is operated continuously to maintain a pressure differential between the ion source chamber and the mass separator interior, sufficient to compensate for the gas flow into the ion source.

Within the casing 38 is a series of grids identified alphabetically A-M, all perpendicular to the axis of the casing and spaced axially in a certain order. The grids are preferably of knitted tungsten mesh of about 97 percent open area, to offer minimum resistance to the beam. The mass separator functions as a velocity filter which accelerates charged masses at its designed resonant velocity and suppresses all other charged masses. This is accomplished by applying alternating potentials to certain grids in a phased relation.

Operation is best understood by referring to the electrical diagram in FIG. 1. It should be understood that the circuitry is only basic, the conventional smoothing, filtering and blocking networks being omitted for clarity, since such details are variable. For purposes of description the apparatus is shown as set up for producing a hydrogen proton beam, with typical power requirements indicated in the table of FIG. 2. This is merely one example, and by suitable selection of voltages, resonant frequencies and other power requirements, the apparatus will produce ionized beams of other gases with either positive or negative ions.

For producing a hydrogen proton beam, an extraction plate power supply 42 is coupled between main anode 26 and extraction plate 28, with the negative side to the extraction plate. A main anode power supply 44, with its negative side grounded, is coupled through power supply 42 to the main anode 26, so that the anode is energized by the sum of the two power supplies. The main anode voltage determines the beam potential and is indicated in the table of FIG. 2 as being 1,000 v. DC. Hydrogen gas ionized by the radio frequency field is thus at the potential of the main anode and includes the three ion species H^+ , H_2^+ and H_3^+ at this point. Extraction plate 28 is at a potential of 850 v. DC, or negative with respect to the main anode, to provide the forward acceleration and beam extraction force by which the ions are ejected through the apertures 30.

In the mass separator 12 the grids comprise, in order, an accelerator grid A, a group of three separator grids B, C and D, a second group of separator grids E, F and G, a third group of separator grids H, I and J, a pair of retardation grids K and L and a final ground reference grid M. The groups of separator grids axially spaced so that the spacing between grids C and F, the center grids of their groups, is equal to five wavelengths of the designed resonant frequency and the spacing between grids F and I is three wavelengths of that frequency. More separation stages and other spacings could be used, depending on the particular ion beam being produced and the species to be separated.

An energy setting power supply 46 is connected between the main anode 26 and grids A and B, with its negative side to the grids, so that acceleration grid A is at a potential of 750 v. DC. This accelerates the ions up to their particular velocity to travel through the mass separator. Due to the difference in masses the protons, or H^+ ions, will reach the highest velocity, while the heavier H_2^+ and H_3^+ ions will be somewhat slower. Grids B-J are all charged by a stepdown bias power supply 48, through stepping resistors 50, to gradually increase the grid potential in steps, the actual voltages being indicated in FIG. 2. In addition, grids C, F and I are excited by a radio frequency power supply 52, the resonant frequency in this instance being 10 MHz. Due to the spacing of the grids at specific multiples of the designed wavelength, the r.f. excitation is in phase in the three separator stages.

For correct velocity resonance the resonant ions should penetrate grids C, F and I at the instant that the r.f. signal is reversing polarity. In these circumstances the resonant ions receive the maximum energy while the non-resonant ions

receive very little. It will be obvious that by proper relation of ion velocity and resonant frequency, the particular ion specie of interest can be separated. The actual separation takes place at the retardation grids K and L, which are energized by a retardation power supply 54 to a potential of 1,060 v. DC. Here the high energy H^+ protons are able to pass but the less energetic H_2^+ and H_3^+ ions are stopped, leaving a pure proton beam.

Grid M is at zero potential and references the beam energy to ground which, since the power supply to the main anode is grounded, leaves the proton beam at the initial main anode potential. Immediately downstream of grid M the beam is space charge neutralized by injection of electrons, as from a small heated filament 56. This prevents coulombic spreading of the proton beam and makes it possible for the entire beam to be directed against targets at some distance from the source, without the need for deflection or focus means. To permit full use of the beam the output end 58 of the mass separator 12 is open, allowing the unrestricted beam to pass into the utilization section 16. An external flange 60 on the output end 58 facilitates connection to a variety of utilization means without obstructing the beam.

The large diameter pure ion beam of constant high flux density is applicable to uses not practical or possible with the usual small beam, or multiple discrete beam apparatus. As one particular example, the nature of the beam closely resembles the known characteristics of the solar wind. Within the large useful cross section of the beam, a considerable area of one or more test samples can be subjected to the simulated effects of solar wind under closely controlled conditions and at high intensities, greatly accelerating the effects.

With the apparatus described it is possible to produce an ion beam on the order of 12 cm in diameter, with ± 10 percent uniformity of density over the entire cross section, at flux densities from 10^7 to 10^{10} ions per square centimeter per second

and energies from 100 to 5,000 electron volts. These figures are by no means limiting and are given only as an example of the performance of a particular apparatus tested. Using the same basic configuration of the apparatus, beam diameters of 30 cm, or even larger, are practical.

I CLAIM:

1. Ion beam apparatus, comprising:

an ion generating source having an output providing a plurality of closely spaced ion beams effectively merging into a single beam on the order of 12 centimeters diameter and of substantially constant flux density across its cross section;

and a mass separator axially connected to said output, said mass separator having means for preferential acceleration of a single specie ion and retardation of other ions, and said separator having an open output end substantially unobstructed and substantially as large as the effective beam cross section to emit from said mass separator a single ion specie beam of like size for use in a utilization device to be connected to said outlet.

2. The structure of claim 1, wherein said ion source includes a chamber having an inlet, a source of gas to be ionized connected to said inlet, and a plate element in one end of said chamber transversely disposed relative to said beams and having a plurality of closely spaced apertures through which ions from said source are expelled into said mass separator.

3. The structure of claim 2, and including an anode in said chamber, a beam energizing power supply coupled to said anode, and an ion extraction power supply coupled to said plate element with a potential less than that on said anode, whereby ions are accelerated through said apertures.

4. The structure of claim 3, and including gas ionizing radio frequency field generating means at least partially surrounding said chamber.

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