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3,265,889

ELECTRON IMPACT ION SOURCE FOR MASS SPECTROMETER WITH
COINCIDENT ELECTRON BEAM AND ION BEAM AXES

Filed Dec. 15, 1961

3 Sheets-Sheet 1

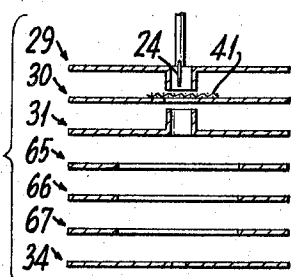


FIG. 8

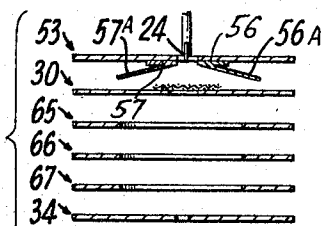


FIG. 9

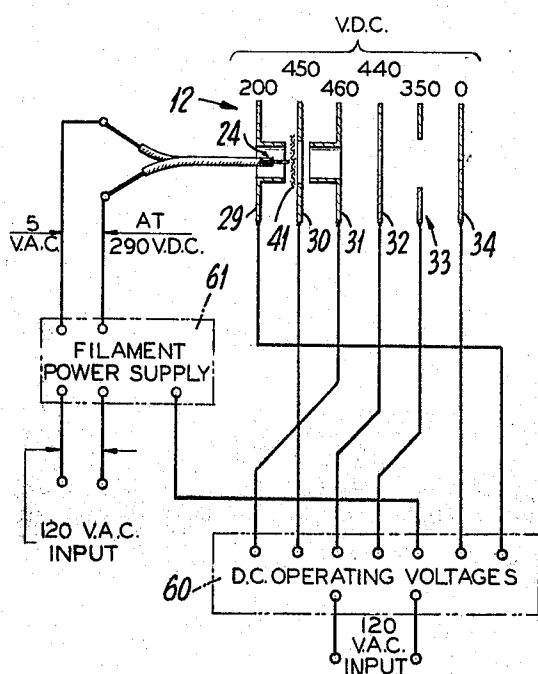


FIG. 7

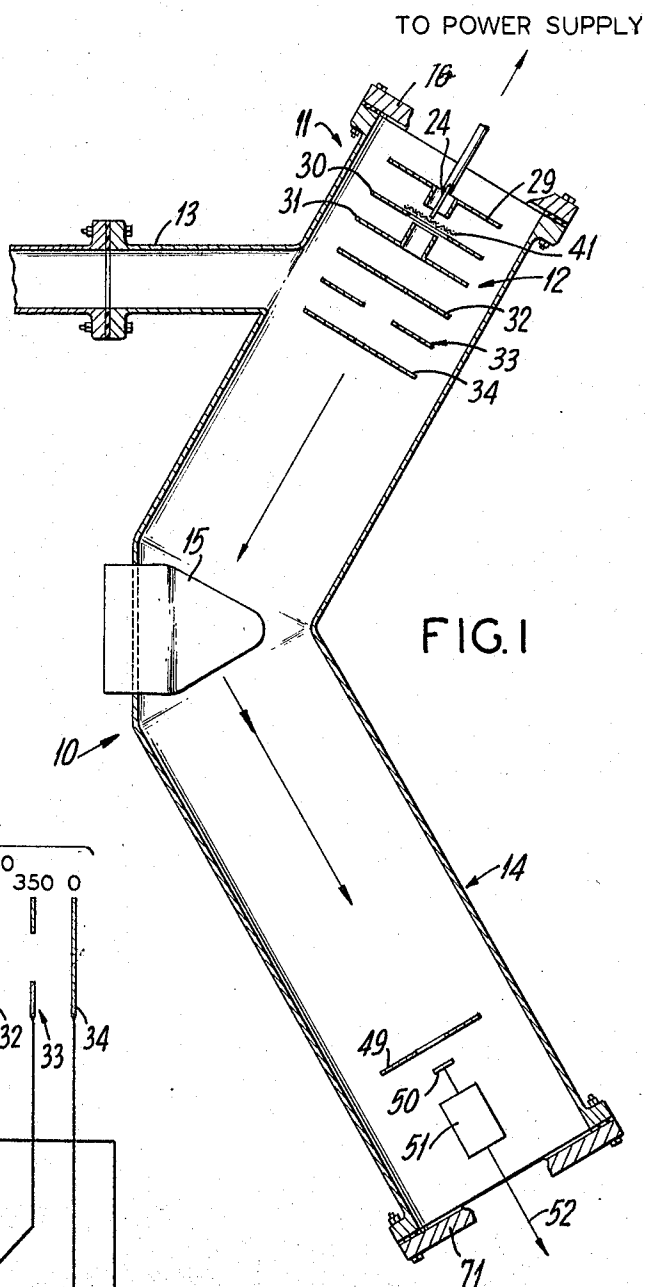


FIG. 1

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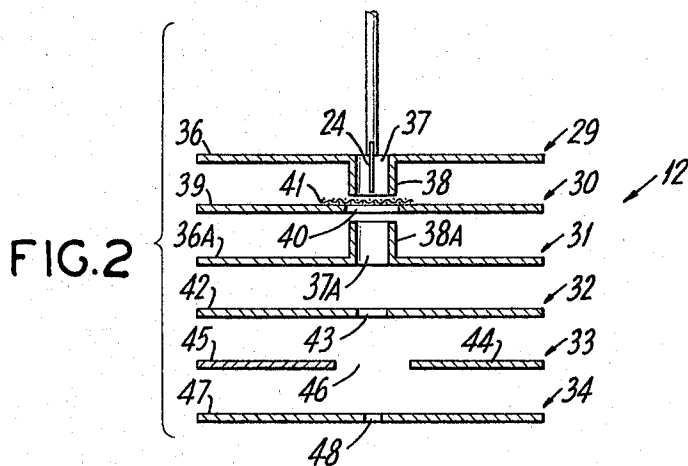
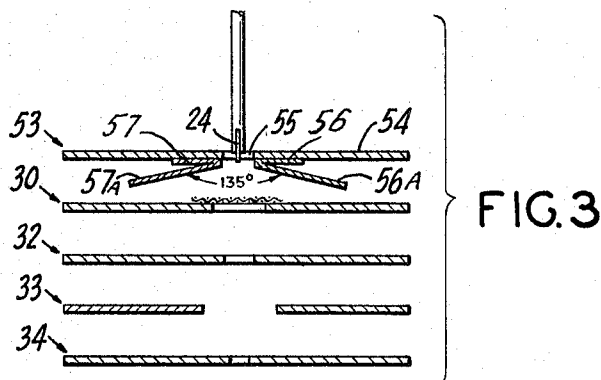
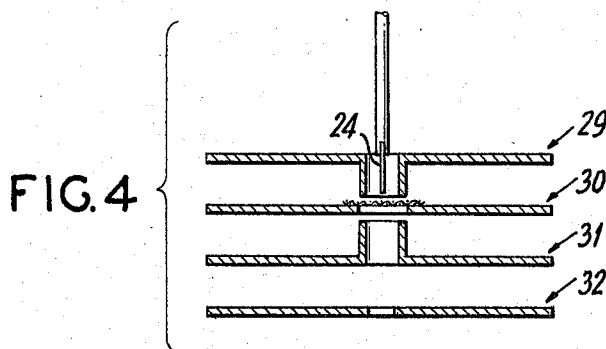
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3 Sheets-Sheet 2



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3 Sheets-Sheet 3

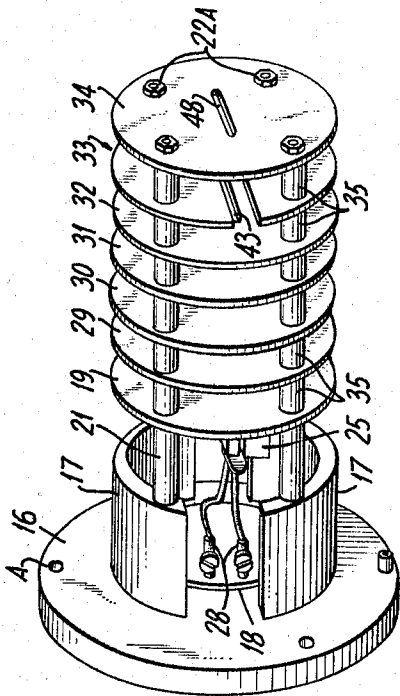


FIG. 5

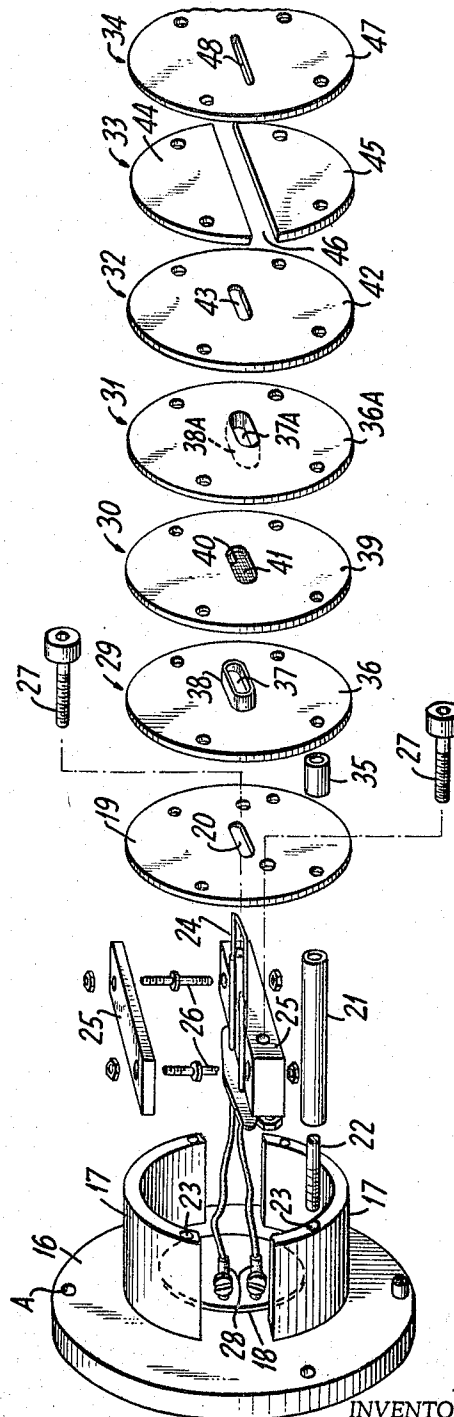


FIG. 6

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ELECTRON IMPACT ION SOURCE FOR MASS SPECTROMETER WITH COINCIDENT ELECTRON BEAM AND ION BEAM AXES

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8 Claims. (Cl. 250-41.9)

This invention relates to an electron impact ion source, and more particularly, concerns an ion source especially useful for mass spectrometric leak detection, for gas analysis and as pressure measuring means of ultra high sensitivity.

An object of this invention is to provide an improved ion source of the electron impact type for gas analysis, which is of simple construction and economical to manufacture.

A further object of this invention is to provide an improved ion source which will provide a maximum stream of ions with minimum energy spread.

Another object of this invention is to provide an improved ion source which includes an electron impact source operating in the absence of a magnetic field.

A further object of this invention is to provide an improved ion source which includes an improved electron impact source operating under discharge or non-discharge conditions.

Still another object of this invention is to provide an improved ion source which is operated at relatively low voltages and has high sensitivity.

Yet a further object of this invention is to provide an ion source of the character described, which does not require a magnetic field at the source region to control the electron beam, yet has excellent sensitivity characteristics.

Still a further object of this invention is to provide an improved ion source which has a non-diminishing sensitivity over extended periods of operation.

Other objects of this invention will in part be obvious and in part hereinafter pointed out.

In the drawings, FIG. 1 is a diagrammatic view in longitudinal section, showing the ion source of the instant invention;

FIG. 2 is a diagrammatic showing of an electrode assembly constituting the ion source of the instant invention;

FIGS. 3 and 4 are views similar to that of FIG. 2 and show alternative embodiments of the invention;

FIG. 5 is a perspective view showing the ion source in assembled form;

FIG. 6 is an exploded view thereof;

FIG. 7 is a schematic diagram showing the electrical connections for the ion source; and

FIGS. 8 and 9 are views similar to that of FIG. 2 and showing further alternative embodiments of the invention.

With conventional ion sources of the electron impact type, the ion output thereof is limited in terms of the electron input to the device, where the value of said electron input does not generally exceed a given level. In the ion source of the instant invention, the electron input thereto may be raised to values which substantially exceed said given level, thereby increasing the ion output of the device.

Furthermore, the ion source of the instant invention is capable of extracting from the ionized volume of gas a relatively higher percentage of ions, to thereby increase the overall sensitivity of the source.

As shown in FIG. 1, 10 designates a mass spectrometer tube of the sector field type, which comprises a leg 11 containing at the upper end thereof the ions source embodying the invention and generally indicated at 12; a gas inlet line 13 communicating with leg 11; the separator

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and collector leg 14 and the usual separator magnet 15 at the juncture of legs 11 and 14. The line 13 also provides means for maintaining the tube under vacuum conditions.

The ion source 12, as shown in FIGS. 2, 5 and 6, comprises an assembly of successive, longitudinally spaced electrodes mounted on a base 16 which has integral arcuate support collars 17 and carries a terminal plate 18. A circular support plate 19 having a central opening 20 in elongated form, is mounted on collars 17 by tubular ceramic insulators 21 and threaded assembly rods 22 received at their inner ends in threaded openings 23 on the outer edges of collars 17.

Gas passing into tube 10 by way of inlet 13 is partially converted into positively charged ions by being subjected to electron bombardment; the electrons being emitted from a tungsten filament 24 of U shape. Filament 24 is clamped between dielectric blocks 25 held together by screws 26; the filament assembly being fixed to plate 19 by screws 27, the forward end of filament 24 projecting through plate opening 20. The legs of filament 24 are connected to terminal members 28 on plate 18.

The electrode assembly 12 further includes a series of spaced electrodes 29, 30, 31, 32, 33 and 34, held in spaced relation by ceramic spacer collars 35 and carried on assembly rods 22 which pass through appropriate openings in said electrodes with nuts 22A on the outer ends of said rods.

Electrode 29 which comprises a circular Nichrome plate 36 with a centrally located, elongated opening 37, has a forwardly extending Nichrome collar 38 about opening 37. Opening 37 is aligned with opening 20 in plate 19, and the forward end of filament 24 projects through opening 37 in electrode 29 to provide a portion of the first stage of focusing of the emitted electrons.

Electrode 30 aids in the focusing and acceleration of the electron beam; said electrode 30 comprises a circular Nichrome plate 39 having a central opening 40 aligned axially with openings 20, 37, and covered with a tungsten wire grid 41.

Electrode 31 is entirely similar to electrode 29 except that collar 38A extends rearwardly of the assembly. Electrode 31 is a second focusing means which focuses the electrons in the vicinity of electrode 32.

Electrode 32, which is the voltage defining electrode and defines the lower energy limit of the ions, comprises a circular Nichrome plate 42 formed with a centrally disposed slot 43 which is axially aligned with openings 20, 37 and 40.

Electrode 33 constitutes the ion focusing electrode which focuses the ions on electrode 34. Electrode 33 comprises semicircular plate sections 44, 45 diametrically spaced as at 46; such space being aligned with slot 43 in electrode 32.

Electrode 34 is a Nichrome plate 47 formed with a centrally disposed, narrow slit 48. Electrode 34 is the grounded object slit to which the ions are accelerated.

Electrode 49 at the lower end of collector leg 14 is the usual suppressor plate, followed by the conventional target 50 and the preamplifier system 51. At target 50, the resultant ion current is detected, preamplified at 51 and then supplied to the usual external amplifier, not shown, by way of cable 52.

In operating device 10, filament 24 provides a stream of electron for bombarding the gas molecules to provide in turn, a stream of ions. The focusing electrodes 29, 30, 31 focus the stream of electrons at the opening 43 in electrode 32. The stream of electrons is accelerated by electrode 30 and moves beyond the opening 43 in electrode 32. Such electron stream is defocused by virtue of the focusing action of electrodes 29, 30, 31 on

electrode 32. Electrodes 32, 33, 34 are also effective as defocusing means for said electron stream.

Beyond opening 43 in electrode 32, said stream of electrons is also decelerated by virtue of the potentials on electrodes 33, 34. The ion stream is focused and accelerated by electrodes 32, 33, 34. It will be apparent that the ion stream moves along the same axis as that of the electron stream emitted by filament 24.

In FIG. 3 is shown a modified form of the ion source 12, which is similar to the electrode assembly described above, except that electrodes 29, 31 are omitted, and an electron directing electrode 53 is provided. Electrode 53 comprises a circular plate 54 formed with a centrally disposed elongated opening 55. A pair of angle plates 56, 57 are affixed to one surface of said plate 54 and on opposite sides of the opening therein. Said angle plates provide divergent leg portions which have a relative angular displacement of about 135°. The forward end of filament 24 extends to the opening 55 in plate 54.

The electrode 53, together with the focusing electrode 30, provides a parallel beam of electrons. Thus, the lower energy limit is not determined solely by defocusing the electrons, as in the previously described embodiment. The lower energy ions are also prohibited from reaching the target 50 by means of the suppressor plate 49, shown in FIG. 1. Plate 49 is made effective by establishing on it a potential such as to prevent low energy ions from reaching target 50. Thus, ions which penetrate this barrier must have a higher energy than the potential imposed by suppressor 49.

In FIG. 4 is shown a further embodiment of the invention. Here the electrode assembly is similar to that shown in FIG. 2 except that electrodes 33 and 34 have been omitted; their functions being assumed by the vacuum chamber itself.

In FIG. 7 is shown the schematic diagram of the electrical circuitry for powering the electrode assembly. The same includes a D.C. power supply 60 for providing suitable voltages for the respective electrodes; and a filament power supply 61 for filament 24.

Whereas the electrode assembly shown in FIG. 3 provides focused ions and a parallel beam of electrons; an electrode assembly, as shown in FIG. 8 provides focused electrons and a parallel beam of ions. The assembly is similar to that of FIG. 2, except that electrodes 32, 33 have been replaced by electrodes 65, 66, 67 which have centrally disposed, elongated openings of substantially enlarged dimensions, as compared to opening 43 in electrode 32.

Also, an electrode assembly, as shown in FIG. 9, will provide a parallel beam of electrons and a parallel beam of ions. Such electrode assembly is similar to that of FIG. 3, except that electrodes 32, 33 have been replaced with electrodes 65, 66 and 67, which electrodes have enlarged central openings as previously described. The number of such electrodes may be varied to produce the desired parallel beam of ions.

The end of leg 11 is closed by a header which comprises essentially the base 16 of the electrode assembly; while leg 14 is closed by a header 71. The headers carry the conventional connector blocks for establishing electrical connections between the power supplies and the ion source 12; and for connecting the output of the pre-amplifier system 51 with the external amplifier, not shown.

It is understood that the several electrodes forming the electrode assemblies described herein, may be formed of various metallic materials including stainless steel, tungsten, tantalum, molybdenum and alloys thereof.

As various changes might be made in the embodiments of the invention herein disclosed without departing from the spirit thereof, it is understood that all matter herein shown or described, shall be deemed illustrative and not by way of limitation except as set forth in the appended claims.

What is claimed is:

1. Apparatus for generating a stream of ions by means of a stream of electrons moving parallel to a given axis, said stream of ions moving colinearly with respect to said stream of electrons, said apparatus comprising an ionizable medium, a source of electrons disposed on said axis, and a plurality of axially displaced apertured electrodes in said ionizable medium, said electrodes including sequentially: a first electron focusing electrode; an electron accelerating electrode axially displaced from said source of electrons; a second electron focusing electrode, said first and second focusing electrodes and said electron accelerating electrode coacting to focus electrons from said source of electrons into a stream converging at a site on said axis at a given distance remote from said second electron focusing electrode; a voltage defining electrode at said site, said voltage defining electrode defining the initial energy of ions formed in a region in the vicinity of said site; an ion focusing electrode; and an object electrode, said ion focusing electrode, said object electrode and said voltage defining electrode coacting to extract, focus and accelerate the ions formed in said region into a stream of ions moving parallel to said given axis and beyond said object electrode, and for preventing electrons within and ions formed within the region between said voltage defining and object electrodes from moving beyond said object electrode; said electron accelerating electrode, said second electron focusing electrode and said voltage defining electrode coacting to prevent ions formed in the region between said electron accelerating and voltage defining electrodes from emerging from said region; and said electron accelerating electrode and said source of electrons further coacting to prevent ions formed in the region between said electron accelerating electrode and said source of electrons from emerging from said region whereby all of said electrodes coact to allow only those ions formed in the region in the vicinity of said site of convergence of said electron stream on said axis to move beyond said object electrode while simultaneously coacting to prevent ions formed in other regions from moving beyond said object electrode.

2. Apparatus as in claim 1 wherein said first and second electron focusing electrodes include collar means about the aperture thereof, said collar means extending axially toward each other.

3. A mass spectrometer utilizing a stream of ions generated by means of a stream of electrons moving parallel to the optic axis of said spectrometer, said stream of ions moving colinearly with respect to said stream of electrons, comprising an ionizable medium, a source of electrons disposed on said optic axis, and a plurality of axially displaced, apertured electrodes in said ionizable medium, said electrodes including sequentially: a first electron focusing electrode, an electron accelerating electrode axially displaced from said source of electrons, a second electron focusing electrode, said first and second focusing electrodes and said electron accelerating electrode coacting to focus electrons from said source of electrons into a stream converging at a site on said axis at a given distance remote from said electron accelerating electrode, a voltage defining electrode at said site, said voltage defining electrode defining the initial energy of ions formed in a region in the vicinity of said site; an ion focusing electrode and an object electrode, said ion focusing, object and voltage defining electrodes coacting to extract, focus and accelerate the ions formed in said region into a stream of ions moving parallel to said given axis and beyond said object electrode and for preventing electrons within and ions formed within the region between said voltage defining and object electrodes from moving beyond said object electrode; said electron accelerating electrode, second electron focusing electrode and said voltage defining electrode further coacting to prevent ions formed in the region between said electron accelerating and voltage defining electrodes from emerging from said region; said electron accelerating electrode and said source of elec-

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trons further coacting to prevent ions formed in the region between said electron accelerating electrode and said source of electrons from emerging from said region; magnetic means disposed along said axis for deflecting the ions in said stream of ions in accordance with the momentum thereof, and ion current measuring means for measuring the current in the deflected stream of ions.

4. A mass spectrometer as in claim 3 wherein said first and second electron focusing electrodes include collar means about the apertures thereof, said collar means extending axially toward each other.

5. Apparatus for generating a stream of ions by means of a stream of electrons moving parallel to a given axis, said stream of ions moving colinearly with respect to said stream of electrons, said apparatus comprising an ionizable medium, a source of electrons disposed on said axis, and a plurality of axially displaced apertured electrodes in said ionizable medium, said electrodes including sequentially: a first electron focusing electrode; an electron accelerating electrode axially displaced from said source of electrons; a second electron focusing electrode, said first and second focusing electrodes and said electrons accelerating electrode coacting to focus electrons from said electron source into a stream converging at a site on said axis at a given distance remote from said second electron focusing electrode; a voltage defining electrode at said site, said voltage defining electrode defining the initial energy of ions formed in a region in the vicinity of said site; and means for extracting, directing and accelerating ions in a stream along said axis away from said site.

6. Apparatus as in claim 5 wherein said first and second electron focusing electrodes include collars about the apertures thereof, said collars extending axially toward each other.

7. Apparatus for generating a stream of ions by means of a stream of electrons moving parallel to a given axis, said stream of ions moving colinearly with respect to said stream of electrons, said apparatus comprising an ionizable medium, a source of electrons disposed on said axis, and a plurality of axially displaced apertured electrodes in said ionizable medium, said electrodes including sequentially: an electron focusing electrode; an electron accelerating electrode axially displaced from said electron source, said focusing and accelerating electrodes coacting to collimate electrons from said electron source into an electron stream

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moving parallel to said given axis, means for introducing an ionizable medium into said electron stream, means for electrostatically directing and accelerating ions formed by the electron bombardment of said ionizable medium into a stream of ions which moves in a beam having a path parallel to said given axis and a second electron focusing electrode following said electron accelerating electrode, wherein said first and second focusing electrodes and said electron accelerating electrode coact to collimate said source of electrons into said electron stream moving parallel to said given axis.

8. Apparatus for generating a stream of ions by means of a stream of electrons moving parallel to a given axis, said stream of ions moving colinearly with respect to said stream of electrons, said apparatus comprising an ionizable medium, a source of electrons disposed on said axis, and a plurality of axially displaced apertured electrodes in said ionizable medium, said electrodes including sequentially: an electron focusing electrode including a pair of opposed plates at the aperture thereof, said plates being in angular divergent relation to each other; an electron accelerating electrode axially displaced from said electron source, said focusing and accelerating electrodes coacting to collimate electrons from said electron source into an electron stream moving parallel to said given axis, means for introducing an ionizable medium into said electron stream and means for electrostatically directing and accelerating ions formed by the electron bombardment of said ionizable medium into a stream of ions which moves in a beam having a path parallel to said given axis.

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